TFW Effectiveness Monitoring and Evaluation Program

Monitoring Effectiveness

of

Forest Practices and Management Systems

Surface Erosion

Study Design Guidelines, Procedures, and Methods

Prepared by:

Joni Sasich, CPSS
RESOURCES
15304 W. Jacobs Rd.
Spokane, WA 99224

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Author’s Note to Users:

This draft, Version 1.1, is the first approximation of the TFW framework developed to assist monitoring evaluations of forest practice effectiveness in controlling the affects from surface erosion. The guidelines within should be used with the understanding that this draft is the first of its kind and requires more extensive review and testing before complete adoption as the TFW framework.

Not all members of the TFW Monitoring Steering Committee are in complete agreement or support of the entire approach. But as in all endeavors of this magnitude, this first draft supports TFW Effectiveness Monitoring Program goals toward implementation. It provides a written format that can be reviewed, discussed, tested, critiqued and revised.

Users of Version 1.1 should bear in mind that they are using a framework model that may change and that they have an important role in participating in modifications and refinements. Your comments and feedback on how to improve this framework model are essential in moving these guidelines to the next level, full implementation.

Table of Contents

Part II: Monitoring Procedures and Methods

Introduction

The TFW Effectiveness Monitoring and Evaluation Program Plan (TFW, 1997), hereafter called "The TFW Monitoring Program Plan," describes the goals and strategy for a comprehensive monitoring program for forest practices. The primary users of the program and its supporting documents, such as this one, are TFW cooperators and the CMER Monitoring Steering Committee.

Three goals are outlined by the TFW Monitoring Program Plan to guide the effectiveness monitoring program and individual monitoring efforts contributing to the program:

1. To evaluate the effectiveness of individual forest practices and restoration measures in achieving aquatic resource protection or restoration objectives on a site scale.

2. To evaluate the effectiveness of forest management systems in achieving aquatic resource protection goals on a watershed scale.

3. To document regional and statewide trends in aquatic resources and watershed conditions.

The TFW Monitoring Program Plan identifies the need for study design guidelines that outline important considerations in developing or reviewing monitoring plans and the need to develop standard methods that provide consistency in evaluation of effectiveness of forest practices. A component of the TFW Monitoring Program is to provide a mechanism for sharing results of individual monitoring projects and aggregating observations from several monitoring efforts to increase certainty in findings. A consistent approach to study design and data collection serves this corporate approach to data management.

The purpose of this document is to provide the framework, under the TFW Monitoring Program Plan, for evaluating the control of fine sediment delivered to the aquatic resource from surface erosion. This document provides guidance for preparation of monitoring plans, procedures for conducting evaluations, and methods of evaluation.

There are two other important sources of fine sediment influenced by forest practices, mass wasting and streambank erosion. Channel scour of 1st Order channels and mechanical erosion of streambanks from logging practices are covered in this document. Subsidence of streambanks from hydraulic energy is not. A framework for evaluating management-related mass wasting is provided in a similar document, *Monitoring Effectiveness of Forest Practices* *and Management Systems – Mass Wasting* and can be obtained through the TFW Monitoring Steering Committee.

The document is organized into two parts: Part I discusses considerations in designing a monitoring project and Part II outlines the procedure and methods necessary to conduct a TFW monitoring project.

Part I: Study Design Guidelines

1.0 General Considerations for Monitoring

Who benefits from monitoring? The TFW Monitoring Program Plan outlines the need to develop an "adaptive management" mechanism whereby TFW cooperators are informed as to how well forest practices and respective management systems are performing and to identify when adjustments are needed to improve effectiveness. A consistent, mindful approach to monitoring and a "corporate" sense toward monitoring will support such an "adaptive management" mechanism.

Monitoring efforts may take various forms: TFW cooperators choosing to focus on issues important to them locally or to meet regulatory requirements; CMER or a group of cooperators may choose to focus on regional issues. Although individual efforts may appear to be unique, there are common threads that will contribute to the overall adaptive management theme. Monitoring cooperators are encouraged to consider the relative contribution to adaptive management, regionally or locally, when developing their monitoring plans.

More recent watershed analysis (Washington Forest Practices Board, 1997) may have watershed monitoring plans or outline recommendations that can help identify specific issues to evaluate within the watershed. Those designing monitoring projects will need to decide whether site scale or watershed scale monitoring best address issues identified from whatever the source.

1.1 Considerations for Monitoring Surface Erosion

Chronic or acute surface erosion can contribute high amounts of fine sediment to the stream network that can affect the aquatic resource in either a suspended form or as a deposit on the stream bottom. Fine sediment in suspension can absorb heat increasing water temperature and can carry pathogens such as giardia and reduce water clarity. Fine sediments settled to the stream bottom, fill voids in the gravels that can reduce dissolved oxygen, habitat space, and habitat availability.

How much fine sediment and under what conditions create adverse affects to the aquatic resource? The answer is not clear. It is likely that minimum thresholds for protection, maintenance, or recovery will vary by geology, stream flow dynamics, natural sediment flux, and aquatic species tolerance. Although our body of knowledge in stream dynamics is growing, much is yet to do to link input, routing and storage mechanisms for sediment with affects to aquatic habitat. In the absence of better information, empirical standards for fine sediment input have been established for regulatory and management purposes. These standards are based on limited observation and are applied widely. The lack of specific threshold data poses a challenge to determining practice effectiveness. This data could lead to establishing a range of desired conditions for fine sediment relative to the natural range in variability experienced by stream systems. Thresholds for fine sediment input would be established relative to the conditions and natural capability of each watershed.

In absence of having these kinds of thresholds for a watershed, the conservative approach has been to manage forest practices and determine effectiveness based on prevention of sediment input. Much effort has gone into developing approaches to controlling delivery of fine sediment to stream channels. This effort includes research in determining erosion hazard and measuring erosion rate from different soil types, identifying the highest sediment producing forest practices, and in refinement of forest practices. Effectiveness monitoring projects have the potential to be an extension of an already extensive set of observations for some forest practices. In some cases, there is no need to duplicate previous efforts in establishing practice effectiveness. Monitoring implementation compliance with a prescription that has been demonstrated as effective may be a more useful approach. Site scale evaluations should be conducted on practices that lack previous effectiveness evaluation.

Research has demonstrated that roads contribute the highest amount of sediment derived from surface erosion of all forest practices. Road-building, heavy traffic on wet road surfaces, and some road maintenance and design practices have been identified as the greatest contributors (Reid and Dunne, 1984; Megahan and Kidd, 1972; and others). Current practices control delivery of fine sediment by trapping sediment during road construction, limiting haul during wet periods, dispersing flow in ditches onto the forest floor instead of into stream crossings, and encouraging rapid vegetative recovery of erosion sources, among others.

Sources of surface erosion other than roads are usually considered less significant. Combined, they may contribute significant amounts of fine sediment in some watersheds. Inventories conducted by numerous watershed analyses have shown that harvest related surface erosion is limited in extent and in duration and less significant than road erosion which can be a chronic source of erosion for the life of the road. Streambank erosion is far less inventoried and thus, its significance is not well understood. Streambank erosion can be caused by logging removing vegetation anchoring banks, from increases in peak flow from hydrologically immature basins, from heavy recreation of grazing trampling, and from natural causes. At first glance, the cause of this source of erosion is not necessarily evident. Recovering landslide scars is another source of surface erosion. Land area comparisons generally indicate fine sediment from eroding landslide scars is not extensive and is relatively short duration. Although, the initial pulse of fine sediment from landslides can be very significant.

A basic understanding of triggering mechanisms for surface erosion, identifying hazard for both erosion and delivery, and a knowledge of forest practices and restoration measures is needed to conduct effectiveness monitoring. The watershed analysis manual (WFPB, 1997) provides an excellent background discussion of surface erosion processes, sediment delivery and the relationship with forest practices.

Chronic and acute forms of fine sediment input can significantly affect the aquatic ecosystem. Chronic sediment delivery persists for years, contributing relatively small amounts of sediment that over time or cumulatively over area, affect sediment supply to the watershed. Evidence of chronic input is often subtle. Acute sediment delivery contributes large amounts of sediment over a short period. Evidence of acute input is more obvious, often forming deposits of fine sediment near the source.

2.1 Site scale versus Watershed scale monitoring

Two scales of evaluation are identified by the TFW Monitoring Program Plan. They provide for different emphasis in evaluating the overall effectiveness of forest practices. They are:

- Individual practice effectiveness evaluated on a site scale
- Multiple practice and management system effectiveness evaluated on a watershed scale

Site scale monitoring is an intensive look at how well individual forest practices control surface erosion and sediment delivery to channels. One or a series of related practices and restoration measures are evaluated for effectiveness in controlling erosion or sediment delivery, or both. Practices are evaluated over varying site conditions. Triggering mechanisms are diagnosed for practices that are not effective so that adjustments are recommended that can be applied with certainty they will improve effectiveness. Practices that are evaluated may be state-approved "Best Management Practices" as defined by standard rules or Class IV special condition by the Forest Practice Act or approved prescriptions from Watershed Analysis, Habitat Conservation Plans or Landscape Plans, and restoration measures.

Watershed scale monitoring provides a big picture view in effectiveness of reducing surface erosion and sediment delivery by forest practices. It provides a means to evaluate performance of management systems such as watershed analysis, habitat conservation plans, standard forest practice rules and landscape plans (under development). Analysis of monitoring results is intended to cover the entire watershed inclusive of all landowners and management systems. Monitoring results are used to demonstrate trends toward meeting aquatic resource goals and to improve hazard identification and, if needed, to adjust management system direction or operation in a watershed.

Guidelines for developing study designs for site scale monitoring of individual practices and restoration measures are covered in Section 2.0 and monitoring procedures are covered in Section 4.0. Study design guidelines for watershed scale monitoring of multiple practices and management systems is covered in Section 3.0. Watershed scale monitoring procedures are covered in Section 5.0.

2.1 Monitoring Approaches

Observing erosion sources and tracing runoff features to a delivery point, or source/delivery is the most direct means for evaluating whether management-related surface erosion or delivery is being controlled. Qualitative evaluations use visual observation methods and are quick and cost effective, allowing for a larger number of observations. Quantitative approaches use a numerical index that reflects increased sediment yield over background. Most methods are time and cost-intensive, often limiting the number of sites that can be evaluated. Neither approach provides an understanding of the direct impact to the aquatic resource. If fine sediment delivery is completely prevented, the conclusion is clear, the aquatic resource is unaffected by management practices. If some sediment delivery is occurring, the conclusion is not so clear. The “How much is too much sediment?” question becomes an issue.

In order to assess “how much is too much sediment” in terms of the aquatic resource, observations of habitat conditions and biological response are needed. Monitoring change in channel morphology and streambed characteristics provides for an indication of habitat condition and can be compared with species viability.

Linking individual forest practices with channel response has proven difficult. Certainty in cause and effect links are confounded by flux in sediment supply and routing, both temporally and spatially (MacDonald,1991; Bunte and MacDonald, 1998; Benda, 1995 and others). It is common for watersheds to have stream segments vulnerable to fine sediment deposition in the lower portion of the basin. Conclusions on origin of the sediment is usually confounded by tributaries having different rate and frequency of input, storage, and routing. This flux in sediment either dilutes or compounds sediment routed to the vulnerable reach and is rarely predictable. This makes tracing the source of sediment observed in the channel difficult. Did the source come from a practice on the hillslope or from a sediment wave existing in the channel?

A network of channel response observations located throughout the watershed integrated with a watershed scale evaluation of sediment input (all sources) may provide better insight to routing mechanisms and sediment flux than monitoring channel response or practices individually. This approach builds a body of observations of source area and delivery to compare with changes observed in the channel. Because of unknown routing mechanisms, temporarily and spatially, commitment toward numerous monitoring sites and long term monitoring is necessary. And, at best, conclusions may only be in terms of trend for the period of monitoring and may not reflect the long-term dynamic of aquatic habitat.

When monitoring channel response or when interpreting the relative effects to the aquatic resource at the watershed scale, study designs should consider including procedures for monitoring all sources of fine and coarse sediment. Study design and monitoring procedures for mass wasting processes are provided in a companion document, *Effectiveness Monitoring of Forest Practices and Management Systems – Mass Wasting.* In future versions, the two documents may be combined. Streambank erosion when evident should also be included.

2.1 Site Scale Evaluation – Individual Practices

Covered in this section is guidance in study design development for site scale evaluation of individual practices and restoration measures. Discussed are elements important to developing a monitoring plan: 1) monitoring goals and objectives; 2) project scoping; 3) developing monitoring questions and hypotheses; 4) a discussion and approach for evaluating effectiveness; 5) considerations for study design; and 5) considerations in analysis and reporting results.

The TFW approach is to evaluate effectiveness through direct evidence of erosion and prevention of delivery to demonstrate performance in achieving protection of the aquatic resource. If a practice or restoration measure is ineffective, the practice and site conditions are further evaluated to diagnose the cause. This diagnosis is used to develop recommendations to improve effectiveness.

2.1 Goals and Objectives

To meet TFW program goals and objectives for site scale monitoring, the following goal and objectives are identified to guide evaluation of individual practices or restoration measures in controlling the effects from surface erosion:

Goal:

Support the TFW monitoring plan by evaluating the effectiveness of practices or restoration measures in protecting the aquatic resource from increased delivery of fine sediment. And, to support adaptive management by conducting monitoring projects that contribute defensible findings of effectiveness and recommendations for improved effectiveness.

Objectives:

1. To evaluate effectiveness of practices or restoration measures in prevention or reduction of surface erosion and/or delivery of fine sediment to the stream network.

2. To evaluate site conditions that influence effectiveness of practices or restoration measures in prevention or reduction of surface erosion and/or delivery of fine sediment to the stream network.

3. Diagnose causes contributing to ineffective or partially effective practices through observing indicators of triggering mechanisms. Provide recommendations for adjustments in practices or restoration measures to improve effectiveness in prevention or reduction of surface erosion and/or delivery of fine sediment to the stream network.

There are several assumptions that help support this goal and these objectives.

Assumptions:

Delivery of fine sediment related to management practices and recovering management-related landslides constitutes an acceleration over natural background rates. Adverse affects to the aquatic resource are suspected at sediment levels accelerated over background rates. Measuring the effectiveness of controlling delivery of fine sediment from practices, restoration measures, and management-related landslide scars provides an indicator of effectiveness in protecting the aquatic resource.

The complex nature of sediment routing make it difficult to determine the relative effect of an individual practice on aquatic resources. Monitoring effects on aquatic resource is best served at the watershed scale. Observing erosion sources and delivery to the stream network from an individual practice is the most clear means of evaluation at the site scale.

Diagnosing the cause of sediment delivery leads to understanding how to improve practice performance. Improving the effectiveness of individual practices in reducing erosion and sediment delivery is expected to provide for maintenance or recovery of the aquatic resource.

2.2 Problem Statement

The first step in developing a monitoring plan is to obtain a clear understanding of the reason for monitoring and to record them in a problem statement. A problem statement summarizes the issues and clarifies the purpose and scope of the monitoring project. It provides focus to the monitoring plan and helps communicate the context for the project to others.

In many cases, the purpose and scope of an individual monitoring effort will be specific to the issues present in a particular watershed. In other cases, the purpose and scope may be derived from regional issues covering several watersheds.

Issues that direct monitoring of individual practices are identified by several means. During watershed analysis, a practice may be prescribed that has been untested in a particular site condition. A widely used practice or restoration measure may require a demonstration of effectiveness over a variety of site conditions. During a 5-year watershed review, a practice may be identified as potentially ineffective and needs further evaluation at the site scale. A review of a practice category may provide information on the relative performance of the practices or restoration measures within the category.

The problem statement may identify priorities for the monitoring project. It defines the type of practice or practices and site condition or site conditions to examine. One should be able to develop monitoring questions and test hypotheses directly from the problem statement. Below is an example of a problem statement:

> *Currently, adding cross drains is recommended to reduce flow of runoff in ditches and to disperse sediment onto the forest floor prior to entry into a stream channel. This practice is used widely in a variety of site conditions. It has been observed that in some conditions this practice can act as an extension of the natural stream network by forming a new channel originating at the culvert outfall. The purpose of this project is to evaluate the relative effectiveness of adding cross drains to reduce sediment delivery and to identify conditions where the practice may be ineffective by creating new channels or gully erosion that deliver to streams. The project will limit its sampling to regions with high intensity storms across a variety of geology or soil types and landforms.*

The issue in this problem statement is that the practice is applied widely and practice performance has been observed to be variable. The purpose of the monitoring project is to evaluate performance under several site condition situations. The scope is limited to areas where high intensity storms present the highest likelihood of performance failure and will apply to several geologic or soil types and landforms.

2.3 Monitoring Questions and Hypotheses

The next step in developing a monitoring plan is to develop monitoring questions and from these questions, hypotheses. Monitoring questions are developed from the purpose and scope of the problem statement. Hypotheses direct the study design and selection of monitoring methods.

A general framework of questions and hypotheses is provided to guide development of project-specific questions and hypotheses for individual project plans. Table 1 outlines examples taken from a few representative Watershed Analysis Prescriptions. These examples illustrate a format and structure to follow when constructing project specific questions and hypotheses. A monitoring plan may have a series of questions and hypotheses or just one, depending on the project scope.

The prescriptions from Watershed Analysis or the Forest Practice Rules, standard or special condition will provide important background for monitoring questions. They identify what practices are to be applied in areas sensitive to sediment delivery. Standard Rules for Forest Practices identify practices to control sediment delivery under general conditions. (The placement of an asterisk identifies the forest practice rules specifically address protection of water quality.) Watershed Analysis identifies triggering mechanisms and specific site conditions that can help in formulating detailed monitoring questions. The "rule call" defines a target condition to evaluate practice effectiveness. Similar information may be obtained from local land managers or state forest practice foresters for practices guided by Standard Forest Practice Rules.

In some cases, a series of practices define a prescription. In other cases, one practice defines a prescription. The choice to include all practices within a prescription or to combine site variables into one monitoring question is an important one. Monitoring questions guide all aspects of study design, i.e., whether one practice or a series of practices are to be evaluated, what parameters are to be measured, the intensity and duration of measurement, and stratification of site factors.

The more practices and site variables included in the monitoring question the more complex the study design becomes. The more variation that is combined the higher risk that there will be less certainty in the relative influence of individual practices or variables. Monitoring Question One in Table 1 presents a case where more than one practice is defined in the prescription. In this example, both the restriction on broadcast burning and requiring log suspension are individual practices that affect surface erosion and delivery to channels. These treatments must be examined individually if their relative influence is to be established, but to address the effectiveness of the prescription, all treatments must be evaluated.

The following list provides examples of the four possible monitoring situations:

- **One practice, one site condition**. This scenario focuses on the fewest variables and therefore, is the simplest of cases. This approach may be used to evaluate a specific practice applied to a defined site condition. An example of this scenario is monitoring culvert placement in a stream crossing using "live" water diversion around the construction site.

- **One practice type, multiple types of site conditions**. This scenario determines the effectiveness of a practice in different site conditions. An example of this scenario is monitoring cross drains applied on a variety of landforms, soil types, and climatic regimes.

- **Multiple practice types, one type of site condition.** This scenario describes a prescription that requires several treatments to be effective. An example is log suspension and no broadcast burning on slope gradients greater than 55% with erosion control measures applied on areas where slope shape does not provide for full suspension. The site condition is the slope gradient and the multiple practice types are log suspension, no broadcast burning, and erosion control measures.

- **Multiple practice types, multiple site conditions.** This is the most complex scenario to monitor. Road restoration measures may provide the best example. Road abandonment requires several treatments to address prevention of sediment delivery. Sidecast pullback, culvert removal and water bar installation are the more common treatments. Treatments can be addressed separately under the previous three scenarios or road abandonment can be addressed in its entirety. Under this scenario, all the included in road abandonment are evaluated under different site conditions, such as, landform and soil type.

Developing a quantifiable hypothesis is recommended whenever it is feasible. However, it is easy to establish a quantifiable test hypothesis that requires an unattainable level of data collection within the resources available. If the objective of the practice is to prevent delivery, and delivery is easily distinguishable visually, why set up a monitoring hypothesis to measure turbidity? On the other hand, if there is a low confidence in visual identification or the relative amount of sediment is important more quantitative methods such as suspended sediment sampling or sediment catchment would be necessary. If resources are limited, a high level of certainty is needed, and a quantifiable result is needed, the monitoring scope may need to be simplified to meet resource constraints. Question Three illustrates two different approaches in test hypotheses, one using a qualitative approach and the other using quantitative approach.

Table 1. TFW monitoring question framework and monitoring question/hypotheses examples – site scale surface erosion.

	TFW Monitoring Question Framework	Project Level Monitoring Question Example	Project Level Hypotheses Example
1A	Are harvest and site preparation practices effective at minimizing surface erosion? When surface erosion occurs, is delivery to stream channels prevented?	*Is no broadcast burn on slope gradients greater than 55% and full suspension cable yarding across all stream channels (i.e. ephemeral, intermittent, and perennial) and on adjacent slopes to channels greater than 55% slopes effective in minimizing surface erosion and preventing delivery to stream channels?*	*Limiting broadcast burning on slope gradients greater than 55% and yarding by fully suspending logs across stream channels and adjacent slopes greater than 55% that drain to stream channels is effective in minimizing surface erosion and preventing delivery to stream channels.*
1B	Are there factors that influence effectiveness?	*Are these practices effective on a variety of soil types and climate regimes?*	*These practices are effective on all soil types and climate regimes.*
2A	Are road construction practices effective at minimizing surface erosion during and shortly after construction? When surface erosion occurs, is delivery to stream channels prevented or minimized?	*Are erosion control measures such as matting, grass seeding, slash filter windrows on fill slopes, and temporary straw bale sediment traps applied immediately after or during construction effective in minimizing surface erosion and preventing delivery to the stream?*	*Erosion control measures applied immediately after or during construction minimizes surface erosion by accelerating vegetation recovery and preventing delivery by trapping sediment before it is delivered.*
2B	Are there factors that influence effectiveness?	*Are these erosion and sediment delivery control methods effective under a variety of soil types, aspects, and climatic regimes? How does timing of application influence effectiveness?*	*The amount of erosion is dependent on the time required to achieve a protective cover on bare soil. The amount of protective cover is dependent upon method, slope angle of bare soil, and for vegetative cover, soil type, aspect and time. Delivery is dependent on time and location of placement of sediment traps and maintenance of traps.*
3A	Are road design practices effective at preventing or minimizing surface erosion? When surface erosion occurs, is delivery to stream channels prevented or minimized?	*Is placement of competent ballast rock with a low percentage of fines on road surfaces that drain toward a stream adequately armoring the surface from traffic wear and minimizing surface erosion delivered to streams?*	*Applying competent ballast rock with fines less than 10% on road surfaces that drain toward the stream is minimizing rutting and fines generation which minimizing surface erosion and delivery to stream.* *OR* *Applying competent ballast rock with fines less than 10% on road surfaces that drain toward the stream is maintaining sediment delivery at the stream crossing within 10% over target amount.*

Table 1. TFW monitoring question framework and monitoring question/hypotheses examples – site scale surface erosion (cont).

	TFW Monitoring Question Framework	Project Level Monitoring Question Example	Project Level Hypotheses Example
3B	Are there factors that influence effectiveness?	*Will effectiveness vary with storm intensity and duration and traffic use?*	*Armoring of road surface is effective in protecting the road surface from rutting and erosion of fines under 100-year storms (representative for the area) and under light to moderate haul (less than 2 trucks/hour).* *OR* *Armoring of road surface is effective in maintaining turbidity levels within 10% over target amount except during heavy truck traffic (greater than 2 trucks/hour).*
4A	Are road management objectives (e.g. inactive, active, abandoned, limiting haul) effective in preventing or minimizing surface erosion? When erosion occurs, is delivery to stream channels prevented or minimized?	*Is recovery of natural revegetation, limiting traffic use, and water bars on inactive roads effective in minimizing sediment delivery to stream channels?*	*On over 90% of the inactive roads traversed, limiting traffic use, installation of water bars, and natural vegetation recovery is an effective means of minimizing sediment delivery by reducing erosion and dispersing runoff.*
4B	Are there factors that influence effectiveness?	*Does soil type, elevation, slope position, or climatic regime influence the effectiveness of drainage stabilization practices e.g. natural revegetation, limiting traffic use, and water bars on inactive roads?*	*Effectiveness of inactive road stabilization practices is dependent on one or more of the following: soil type, elevation, slope position, and climatic regime.*
5A	Are restoration measures (e.g., revegetation, bioengineering) effective in preventing or minimizing delivery of surface erosion to stream channels?	*Is erosion matting and willow stakes providing an environment for vegetation recovery in landslide scars which is reducing erosion and delivery to stream channels?*	*The application of erosion matting and willow stakes has accelerated vegetation recovery over natural recovery reducing the chronic erosion and delivery by over 50% by the second year..*
5B	Are their factors that influence effectiveness?	*Are there differences in site conditions that influence the effectiveness of erosion matting and willow stakes to reduce erosion and delivery to stream channels?*	*Effectiveness of erosion matting and willow stakes is dependent upon aspect, slope gradient, and soil type.*

2.4 Effectiveness Evaluation and Diagnosing Cause

Effective practices either reduces sediment delivery by controlling erosion in areas that have a potential for delivery or by catchment and dispersal of sediment onto areas that do not contribute to the stream network.

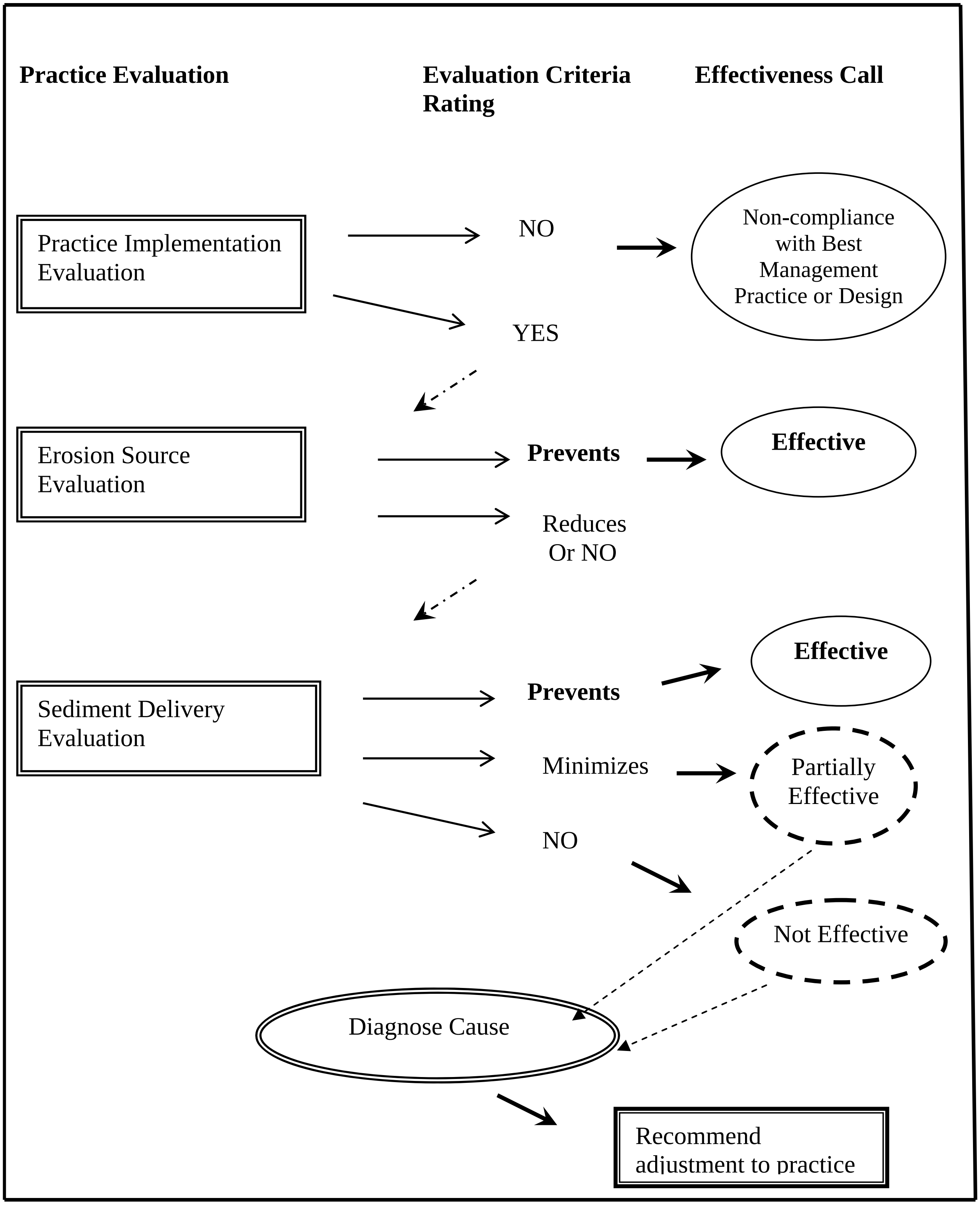
Attempts to establish forest practice effectiveness date back to 1980 when the Washington Department of Ecology (DOE) published results from a survey of effectiveness of Best Management Practices (Sachet, et al., 1980a; 1980b). This survey was primarily on implementation and subjective determinations of effectiveness. Most of the impacts to water quality were found to be from non-compliance, practices either not implemented or implemented incorrectly.

A subsequent study funded by the State of Washington and Environmental Protection Agency, and sponsored by TFW, was conducted from 1992 through 1995 (Rashin, et al., 1997 review draft). Effectiveness of Best Management Practice was monitored using a "weight-of–evidence" approach to evaluate effectiveness. Eighty-six examples of four practices were evaluated on 36 different study sites over nine physiographic regions in Washington state. A combination of survey techniques where used to gather evidence of effectiveness for each practice example. Surveys included erosion surveys, visual signs of sediment delivery, in-stream suspended sediment/turbidity monitoring (above/below and near source), and aquatic habitat surveys. Evaluation of effectiveness was based on combining observations from different survey methods. Each practice received a minimum of two methods of evaluation. If all surveys evaluated the practice as effective, the practice was rated effective. If one of the survey results rated the practice ineffective, the practice was rated partially ineffective. The study states that a finding of "effective" indicates there is a high degree of confidence that water quality standards have been met, although an effective call should not be misinterpreted to satisfy compliance with the regulatory water quality criteria.

The approach to evaluating effectiveness covered in this document attempts to strike a balance between what is practical to accomplish with some level of confidence in the findings. It employs the use of direct evidence through visual observation or measured delivery compared with standards accepted as the state of the knowledge to date. Comparing measured sediment input to a standard provides a level of consistency and objectiveness in reporting effectiveness or partial effectiveness.

The following diagram in Figure 1 outlines a systematic approach to reaching a conclusion about effectiveness for an individual practice or restoration measure. This approach can be used with qualitative and quantitative evaluations. Briefly, the approach begins with an evaluation of implementation compliance of the practice, followed by evaluation of erosion. Further evaluation of sediment delivery occurs if erosion is observed. If sediment delivery is observed, the cause is identified and reported. Improvements to the practice to reduce fine sediment delivery relative to site conditions are then recommended.

Figure 1. Effectiveness evaluation flow chart



In more detail, the first step is to evaluate practice compliance with the management guidance for the site, (i.e., Watershed Analysis prescription, Habitat Conservation Plan, or Forest Practices Standard Rules or Special Conditions). Practices not implemented according to the guidance are considered not in compliance with Best Management Practices and indicates a high likelihood for not meeting water quality standards. The site with a non-compliant practice is documented but removed from the pool of candidates for effectiveness monitoring. This monitoring step provides a screening tool to assure only sites representative of the practice are evaluated. Documenting the practice sites not in compliance provides an evaluation of implementation effectiveness of management systems. Sharing this information with local managers offers the opportunity to make corrections and to meet the adaptive management goal.

Next, the compliant practices are evaluated for whether surface erosion is associated with the practice. If erosion is observed, a sediment delivery evaluation is conducted. Only sites that are evaluated as preventing or avoiding erosion would receive an effective call at this point. Any signs of erosion would lead the examiner to conduct a sediment delivery evaluation. If there is no evidence of sediment delivery to a stream channel or evidence that delivery has been prevented, the practice are considered effective.

A partially effective practice is one that has significantly reduced sediment delivery but delivery to a channel is still occurring. Ineffective practices are those with visible or measurable evidence of significant sediment delivery. A standard or target for quantitative methods of “What is significant?” has been established by the surface erosion module of watershed analysis (WFPB, 1997). Sediment delivery of 50% or greater increase over background or the control is considered significant. Partially effective practices are those with 10-50% increase over background or the control. Less than 10% increase is considered within measurement error or not significant. For qualitative methods, it is assumed that only significant amounts of sediment delivery can be observed by visual observation methods. (Note: It is recognized that these standards are more useful in providing consistency in evaluating and reporting results than to indicate a true effect to the aquatic resource. At the site scale, it is difficult to relate cause and effect between a practice site and the aquatic environment through direct evidence. The only exception is when sediment input is obviously overwhelming which is rarely the case. The next step is most meaningful to the TFW Program goals.)

Both, ineffective and partially effective practices are routed through the diagnosis step. This step provides the evaluation of the causes and triggers of delivered sediment from the practice. Recommendations for correction or change in the practice to reduce sediment delivery is made.

The question will arise, “After observing multiple sample sites of one practice, some were rated effective and others were only partially effective. Was the practice effective?” This question is best resolved through diagnosing each site situation. The range in effectiveness may be due to varying site conditions or differences in implementation. Again, it is probably more useful to document the percentage rated as effective and partially effective and then, document the reasons for the range than to attempt to summarize observations into one category of effectiveness.

Individual monitoring plans should discuss what specific criteria will be used to evaluate practice compliance, erosion, and sediment delivery. These criteria may need to be created specifically for the monitoring method, practice or site condition of the project. Using an example, evaluation criteria is outlined following the pathway in Figure 1. In order to develop criteria it is necessary to have selected a monitoring method. Selecting a monitoring method is discussed in Section 2.4.5.

Example: Evaluation Criteria for determining effectiveness example

Monitoring Hypotheses: Application of filter strip windrows during road construction prevents delivery from the roadbed and fillslope by trapping sediment from erosion of new construction.

Implementation Compliance Evaluation Criteria: Filter strip windrow is placed along fill during road prism construction. As specified in the design, as a priority if materials are limited, windrow construction will be located in areas with potential delivery to a channel.

Monitoring Method Used: Level Two – Photo point method

Evaluation Criteria used:

> *Effective Practice: Sediment deposited in windrow. No signs of runoff from road bed delivering to stream channel. No signs of runoff carrying sediment deposited in window to a stream channel.*
>
> *Not Effective: Runoff trails through filter windrow to stream channel. Deposits of sediment near and in channel associated with runoff trails.*
>
> *Partially Effective: Visual observation monitoring method does not allow for partially effective evaluation.*

Indeterminate Results

There may be cases where an effectiveness call can not be made. In most cases, an entire data set of observations for a practice will not be indeterminate. The only circumstance where this may arise is if the method chosen does not provide for adequate evaluation of the practice. This can be avoided by pilot testing the method on a few site representative of the monitoring project to assure that it will adequately measure practice effectiveness.

If only a portion of the data set is found indeterminate, the relative percentage of indeterminate sites are reported with the percentage of effectiveness findings. The indeterminate finding is diagnosed and the reason why is reported. This step may help others to avoid indeterminate results.

Basis for making indeterminate finding are:

- Outside interference (e.g., animal disturbance, tampering with site did not allow adequate evaluation of a particular practice)
- Survey method was not appropriate for site specific conditions or practice type
- Site factors, usually weather related, were not present during survey (such as storm runoff events needed for road sediment delivery surveys)
- A suitable control could not be found for a survey technique that required one and no other survey technique was applicable

Diagnosing Causes of Sediment Delivery from Management-Related Surface Erosion

Diagnosing the cause of the failure leads to better understanding of the interactions of the practice with site factors. This leads to defensible recommendations for improvements. One of the benefits of conducting effectiveness evaluations that track the pathway of sediment from source to delivery point is that throughout the survey there is an opportunity to observe the contributing causes of failure or success of a practice. Essential to diagnosis is the ability to observe signs left by different erosion processes and to recognize primary and secondary factors contributing to erosion or delivery. It is also important to collect enough site condition information so influences of site factors can been evaluated.

Questions to have in mind when evaluating why a practice was not effective are:

- What triggers are present causing erosion? Was the practice designed to control or reduce the potential for these triggers?

- How is sediment transported from the erosion source? What is the distance between the source and delivery point? Was the practice designed to control or reduce transport?

- How does the failure of this practice compare to a worse case scenario?

A field key for diagnosing triggering mechanisms for road and hillslope erosion is provided in Appendix B. This key outlines the more common indicators for triggers and lists practices that address these triggers in certain site conditions.

2.5 Design Elements of Monitoring

This section covers design elements of a monitoring project. Elements carefully outlined in the monitoring plan should be: 1) the use of stratified sampling and identification of situational categories; 2) site selection; 3) the sampling schedule; 4) level of certainty and sample size; 5) monitoring methods and; 6) data analysis and reporting results.

2.5.1 Stratification

Stratification is a useful tool in monitoring of uncontrolled settings such as in the natural resource environment. Efficiency is improved by organizing variables into distinct sample sets. Sensitivity of the analysis can be enhanced by reducing the amount of variability or by grouping known variability into sample sets of predicted outcomes. These are called "situational categories".

The TFW Monitoring Program Plan suggests that a statewide system for stratifying monitoring situations would facilitate data management, aggregation of data sets to increase certainty in results through larger sample sizes, and extrapolation of findings, regionally. The discussion on stratification for surface erosion monitoring at the site scale is presented here to meet this expectation.

Presented is a hierarchical approach to stratification. This provides flexibility for statewide and local study design needs and allows for extrapolation of results to similar situations. A problem statement in a monitoring plan may identify the need to evaluate the effectiveness of road maintenance practices over site conditions representative for the state. Another problem statement may identify the need to evaluate a certain road maintenance practice (e.g., rock weirs as sediment traps in road ditches) in a particular watershed. Both of these monitoring projects are greatly assisted by stratification. The first example identifies multiple practices and multiple site conditions, the second example identifies a single practice under several site conditions. The regional stratification system provides a framework for both.

Site characterization often is confused with stratification. Groupings for stratification are purposefully broad. These groups are used to categorize similar basic attributes and to make useful distinctions for cataloguing observations and for site selection. They delineate situations of similar conditions and distinguish meaningful differences. They can be used to describe site conditions in general, but some site conditions may vary within a strata. Site characterization is an important companion to stratification. The purpose for site characterization is to collect data specific to the site being evaluated in order to understand how specific site conditions influence effectiveness. Site conditions are used in diagnosing causes of failure in effectiveness. Both site characterization and stratification are used in developing recommendations for improvement. Stratification is used to compile monitoring results and to extrapolate to similar landscapes.

In identifying situational categories, monitoring plans should follow the framework for site conditions and practice types presented in the following discussion. The framework has been designed to be sufficiently broad to allow for all possible situations. Consistently identified situational categories will provide the foundation of the TFW regional database.

2.5.1.1 Regional Stratification of Site Conditions (provisional)

{Note: This approach is under further evaluation and review. Users are encouraged to use this framework with this understanding. Comments should be submitted to the TFW Monitoring Steering Committee}.

Climatic regime is the first layer and is defined at the largest scale (e.g., 1:350,000 – 1:500,000. Soil parent material group is the next layer and is defined at an intermediate scale using geologic resource mapping (e.g., 1:100,000 – 1:250,000). The third layer is Landtype which is delineated at the watershed scale (e.g., 1:24,000) and is defined by a combination of landform and soil parent material groups.

Climate

Physiographic Regions of Washington summarized in Pentec (1991) provides a division of the state that represents a surrogate for climatic regimes. It is based on a composite of Fiksdal and Brunengo (1980), Gallant (1986), and McDonald and Ritland (1979). These climatic regimes represent areas of similar storm recurrence, intensity, and duration. An additional climatic regime has been added to the original map, Olympic Rainshadow. Figure 2 is the map from Pentec (1991) with the new addition.

Figure 2. Physiographic Regions of Washington

Monitoring plans should identify which physiographic regions are pertinent to the project. Selecting monitoring sites in different physiographic regions should assure evaluation of varying site conditions if that is one of the objectives of the monitoring project. To serve local or regional interests, subcategories may be identified further. These subcategories would be identified within these regions to assure consistency with the statewide stratification layer. An example of a subcategory may be a change in precipitation amount or type possibly indicated by a different composition of tree species (e.g., subalpine fir plant associations versus ponderosa pine plant associations).

Soil Parent Material Types

Physical properties of soils influence surface erosion potential and to some degree, transport. In the Pacific Northwest, soil parent materials weather into predictable soil texture with predictable cohesion and transport properties. The statewide framework identifies groups of bedrock or surficial deposit types that produce basic soil differences. These groups are identified in Appendix A.

Soils that have a significant difference in physical properties in their surface layers from subsurface are distinguished for hillslope erosion monitoring. Subsurface layers are more relevant to road-related practices than surface layers, as surface layers are stripped away or mixed during construction.

There are two scales that apply to this stratification. At the statewide level it may be quite time consuming to identify sites with differing surface layers. It may be more practical to select general project areas then further stratify by soil surface layer differences, if needed. Of course, it depends on the problem statement. An exception is when surface layer properties are the target of a problem statement.

Subcategories should be created if needed to adequately address the variability on the local level. Although, careful consideration should be made before adding subcategories to whether the addition describes a inclusion of small extent or a large area. Stratifying inclusions will serve to devote precious resources in evaluating a small and potentially, less significant situation. Many subcategories may be handled through site characterization.

Results for subcategories as well as regional categories should be reported to accommodate regional consistency goals while not masking potentially important findings in the subcategory. An example would be where a complex sedimentary bedrock group includes vastly different soil properties. By definition this group is broadly defined. Most geology resource maps group complexly layered or faulted bedrock because mapping scale and intensity does not allow for more detail. This detail may be very relevant to findings. There are two choices: identify subcategories during site selection once the project area is selected or document the variability through site characterization.

The monitoring plan should describe situational categories within the context of both statewide stratification and any additional subcategories.

Landtypes (provisional)

Landtypes provide a third layer of stratification combining landform features and parent material/geology groups to identify situations of predicted differences in surface erosion or fine sediment delivery potential. Linked to geomorphic process, landtypes broadly stratify differences in stream density, slope gradient, slope complexity (shape and length), efficiency in routing fine sediment, and hydrologic regimes e.g. rapid runoff response to storms.

Landtypes provide a consistent means for extrapolation of results. They also are essential in establishing reference conditions for comparing management-related surface erosion and delivery with natural background.

At this point, landtype mapping is not available. Landtype concepts can be used to direct selection of candidate project areas. Once project areas are identified, landtypes are delineated and used in the site selection process. Appendix A provides instruction on development of landtype concepts.

Monitoring plans should outline what landtypes will direct site selection and the procedure used to identify landtypes.

Proximity to Stream Channel

Delivery of fine sediment to the stream network from road and hillslope erosion is directly correlated with distance from the erosion source. This site factor is an important inclusion in situational categories for surface erosion.
Four broad categories are defined:

Table 2. Erosion source proximity to stream channel categories

Stream Proximity
Close: 0-100 feet
Mid: 100-200 feet
Far: 200-200 feet
Within or outside of a contributing area
(A contributing area is defined as the area draining directly to a stream channel.)

Monitoring plans should identify how proximity to the stream channel applies to study design, either in stratification or site characterization. Plans should describe how site selection is determined based on this strata.

2.5.1.2 Local Stratification of Site Factors

Soil Parent Material Types

The statewide stratification categories provide useful stratification for project level monitoring. Subcategories may be designed when pertinent to the project area and where soil differences significantly influence soil erosion processes or practice performance. Examples may be different density of glacial till (e.g. dense, cemented, or not compacted), and in the sedimentary groups where bedrock layers produce soils with significantly different erosion situations.

Slope Gradient

Slope gradient groups in Table 3 and 4 represent three categories that are developed from documented hazard rating systems. They have been adjusted slightly to incorporate current slope gradients identified in prescriptions that reduce hazard. USGS 7.5 minute quadrangle maps can be used for initial stratification of candidate sites but it is recommended that the gradient be verified in the field.

Table 3. Slope Gradient Categories for Hillslope Erosion and Sediment Transport Potential.

Slope Gradient Category	**Erosion Potential**	**Sediment Transport Potential**
0-15%	Low	Low
15-30%	Moderately Low	Moderately Low
31-55%	Moderate	Moderate
>55%	High	High

Table 4. Slope Gradient Categories for Road Erosion and Sediment Transport Potential.

Slope Gradient Category	**Cutslope Erosion[1] Potential**	**Sediment Transport Potential[2]**
0-30%	Low	N/A
31-65%	Moderate - High	N/A
65%	High	N/A

[1]Cutslope angles and length increase with increasing slope gradient. As cutslope angle and length increase vegetation recovery is more difficult and erosion hazard increases. Erosion hazard and vegetation recovery on road fillslopes tend to be less gradient dependent and more related to soil texture and climate.

[2] Not applicable. Transport is dependent on road design and location.

2.5.1.3 Stratification Categories of Practice Types

There are numerous variations of forest practice types and restoration measures. Specific practices are prescribed during watershed analysis individually by watershed. Forest Practice Rules provide a minimum standard for practices statewide and Class IV Special are practices prescribed specifically for a unique site condition under the Forest Practice Application process. Table 5 outlines activity categories and practice categories for cataloguing individual practices and restoration measures. These categories can also be used in study designs to stratify multiple practices to be evaluated at the site scale.

If the individual practice or measure to be evaluated does not fit within a practice category, use the activity category to catalogue the practice and list the practice. Monitoring plans and reports should provide both categories and a detailed description of the practice or restoration measurements being evaluated.

Table 5. Practice Type Situation Activity and Practice Categories.

Activity Category	**Practice Categories**	
Road Design/Construction	Location Drainage Road prism	Erosion Control Sediment delivery control Stream crossings
Road Maintenance Practices	Drainage Road surface Disposal of maintenance spoils	Erosion control Sediment delivery control Sidecast Removal
Harvest	Aerial (e.g. cable, helicopter)	Ground-based (e.g., tractor, feller/buncher)
Site Preparation	Slash burning Tractor pile	Tractor scarify Herbicide
Restoration/ Mitigation	Revegetation (e.g., seeding, planting, erosion mats) Bioengineering (e.g. cribwalls, wattling) Road obliteration or “put to bed”	Stream crossing Sediment retention Disposal Sites

Road management/use levels can produce a different outcome from the same triggering mechanism. Stratifying studies of road maintenance practices by the following categories is recommended:

Table 6. Road management/use level categories

♦ Active: light to moderate traffic	♦ Inactive
♦ Active: heavy traffic or haul	♦ Abandoned

2.5.2 Site Selection

Candidate sites for monitoring are identified based on situational categories to be evaluated. For the earlier problem statement example in Section 2.2, below is a possible scenario for identifying candidate sites using the TFW stratification approach:

Example:

> *Soil parent material groups are used to identify a variety of geology or soil types. Landforms are generally identified using the statewide list of landforms. If landtyping is available, this step can be combined using the landtype map. Funding and personnel limit examination of all possible variation of geology and landform so several site situations are chosen. For this example, combinations are chosen based upon the largest land area represented by geology group and landform and on the geology group or landform where cross drains have been suggested or predicted to be ineffective. The number of site situations chosen are ten. We are assured that this number will give a range of representative and commonly occurring site situations. Roads with cross drains are identified within the areas identified for the chosen site conditions. These roads become the candidate pool of sites for monitoring.*

Most statistical texts will suggest selection should be random from the entire population. Random selection from all possible sites is not a problem if precise location is not important or the variables are known or the number of variables are few. This is not the case in natural systems (MacDonald, 1991). In the example, the number of variables has been reduced to represent site conditions that occur more frequently and site situations where ineffectiveness is predicted. This greatly increases efficiency in focusing on a few important variables but maintains a range of representative variables for the study, at a reasonable expenditure of cost and time.

Assuring the candidate sites are in locations that are representative of the situation to be tested greatly increases efficiency of the evaluation. To reduce the likelihood of spending time evaluating a site that is not representative, the next step screens candidate sites for the final pool of candidate sites. This screening is a combination of an office exercise and field reconnaissance.

Candidate sites are screened using the following criteria:

- Practice at candidate site was not implemented according to the prescription and is not representative of the practice.
- Evaluation requires a reference or control site. Candidate site lacks a representative control site that is isolated from practice effects or other non-representative variability.
- Interaction with other practices can not be adequately separated at the candidate site.
- Operations or completion of the candidate site do not allow for evaluation of effectiveness at the optimum time.
- Field reconnaissance verifies candidate site is not representative of site conditions or practice being tested (e.g., slope gradient, soil type).

Candidate sites that pass this screen become the pool from which the final selection of sites is made.

Monitoring plans should outline the process and what criteria will be used in site selection. Monitoring reports need to summarize the process and the criteria that was used for site selection and discuss the level of confidence in the sites evaluated in representing the issues outlined in the problem statement.

2.5.3 Frequency and Timing of Sampling

Sampling timeframes vary with the practice and monitoring methods, as summarized in Table 7. Visual observations of soil loss and delivery require observations either during or shortly after the erosion/delivery event. Follow up visits may be necessary depending on the methodology. Observations before and after the practice may offer the best insight using the “before” observation as a reference for a changed condition observed after practice implementation.

Road Construction

The highest amount of sediment delivered from roads during and shortly after construction (Megahan and Kidd, 1971). Depending on precipitation, roadfills and cutslopes may take up to 3 years to stabilize after construction. Construction of stream crossings can deliver short duration, high magnitude amounts of sediment. Visual signs of delivery from stream crossing construction is often removed by the first storm event after construction. Signs of delivery from other road construction practices are best observed during the first storm event. Therefore, the best time to monitor for effectiveness of sediment reducing practices is during construction at stream crossings and the entire road length within the first year after construction.

Road Maintenance

Stable cutslopes and particularly fillslopes tend to revegetate, reducing erosion over time. Road surfaces and unvegetated ditches continue to contribute sediment over the life of the road. Amount of sediment from these sources increase with traffic use and maintenance frequency. Maintenance of drainage structures provides a contradiction for sediment delivery. Lower maintenance frequencies tend to allow ditches to revegetate which filters sediment from ditch water. With ditches acting as sediment traps, flow capacity is diminished which places a higher risk in runoff diversion over the road surface and fillslope causing more erosion. More frequent maintenance removes sediment, often undermining the toe of the cutslope causing sloughing into the ditch which creates the sediment cycle all over again.

The time of year and aspect may have an influence on the amount of sediment yielded from roads. A literature review (Ramos, 1997) notes that the Silver Creek Watershed Research on the Boise National Forest found that fall road catchment samples yielded more sediment that spring samples. Ramos (1997) attributes the higher sediment yields to higher storm frequency and intensity in the fall and possibly lower soil cohesion from summer drought. Higher sediment yields were measured from roads with southerly facing cutslopes than other aspects. These results are most likely transferable to eastern Washington, but no comparable study was cited for climates similar to Western Washington.

It is recommended that if at all possible and when it is safe to do so, erosion and transport processes are evaluated during storm events. Measurements of soil loss are best conducted shortly after storm events. Delivery distances are most accurately measured during storm events when runoff is observed. Measurements of delivery distance after runoff has dissipated must rely upon secondary indicators such as vegetation bent over in the direction of runoff, rills, and gullies.

Road Use Level

Numerous studies have identified that the amount of sediment produced from roads is directly correlated to the amount and type of traffic, with frequent truck traffic producing the highest sediment yields. Sediment reduction practices commonly employed are application of erosion resistant surfaces, limiting haul during wet periods, and using sediment traps. Practices intended to address this issue should be monitored during the times when highest amount of sediment is expected (i.e., wet weather and representative traffic use).

Road Abandonment

Some aspects of road abandonment are similar to road construction. Sidecast pullback, ripping of the road surface, waterbar construction and culvert removal are all activities that expose fresh bare soil to erosive forces. “Pulling” culverts from stream crossings with deep fills can generate acute sediment delivery over a short duration and provide chronic direct delivery for several years after as the stream reconstructs its channel. Mitigating practices encourage rapid revegetation and stream crossing restoration techniques that remove all fill and reconstruct the stream’s channel and floodplain. To capture potential high magnitude short duration delivery events, monitoring needs to occur during operations or during or shortly after the first storm event. Effectiveness evaluation for chronic sediment delivery is appropriate between 1-3 years after abandonment understanding that complete recovery many take several years.

Harvest

The first evaluation should take place within a year after logging and ideally during the first storm event or shortly after. If sediment delivery is observed, re-evaluation should take place one to two years after the first to evaluate whether delivery is prolonged or short lived.

Restoration

Monitoring vegetation recovery or bioengineering treatments involving revegetation should be after the first growing season and again during the third growing season. Monitoring for evaluating long-term objectives is dependent on the treatment. For most treatments, a third observation at ten years after completion and every five years until restoration objectives are met should be adequate. For road obliteration or other drainage stabilization measures, an additional monitoring should be scheduled to coincide with a severe storm event.

Table 7. Time scale for sampling surface erosion (includes hillslope, road and channel bank) and sediment delivery to stream channels

Management Activity	Monitoring Method Type		
	Implementation Survey	**Erosion source and Sediment delivery surveys**	**Sediment Yield In-stream monitoring**
Harvest Unit Design and Operations	Immediately following harvest.	Immediately following harvest and one year following. Pre-harvest survey of channel bank condition.	Pre-harvest sediment yield/stream flow baseline; above and below practice during through one year following.
	Immediately following broadcast burn	Storm event within two years after broadcast burning	Same as above. Samples should continue for two years.
Road Design/Construction	During and immediately following construction.	Immediately following construction and after the second year (two growing seasons).	Pre-construction baseline; paired sample (e.g. above and below) during and up to four years following completion.
Road Maintenance	Immediately following activity.	Next storm event following activity.	Same as above.
Road Management (Traffic use, inactive/active/abandoned)	During storm event and representative use.	During storm events.	Pre-activity baseline. Paired sample (e.g., above and below during use and/or representative runoff events.
	Abandonment similar to construction.	Abandonment similar to construction.	Abandonment similar to construction.
Restoration	Immediately after treatment.	After first and third growing season plus long-term measurement (e.g., at 10 yrs).	Pre-calibration baseline. Paired sample (e.g. ,above and below) for 3-10 years.

2.5.4 Sample size

MacDonald (1991) states, "the ability to detect a difference between two populations is a logarithmic function of sample size rather than a linear function. This means that increasing the sample size may make a substantial difference if there are very few samples (e.g., less than five or ten), but the benefits of increasing the sample size beyond about thirty or forty generally are very small."

For all but the simplest of sampling designs, time and resources will limit the ability to achieve a high level of statistical significance through large sample sizes. In other cases, stratifying carefully to assure that the array of practice types and site conditions are compared appropriately will limit the available candidate pool. The best approach is to have confidence in the sites undergoing evaluation by conducting the screening scheme suggested in Section 2.4 and to observe the maximum number of sites within resource constraints. Trend data collected from quality test sites is far better than collection of data with a high amount of background noise. The accumulation of observations made in a consistent manner over time will provide the level of evidence and with it, certainty in practice performance.

2.5.5 Methods

Selection of sampling methods are based upon the following:

- Purpose and scope of the project
- Type of question to be addressed
- Certainty needed in the results
- Preference for quantitative or qualitative results
- Availability of funds, technical expertise, and personnel

Monitoring plans should outline the basis for selecting a certain evaluation method. The list above provides a format to show the rationale for the choice in monitoring method.

In some cases, more than one method is recommended to build certainty. This has been suggested by Rashin, et al (1991) as the "weigh-of-evidence" approach.

Table 8 provides a matrix for selecting monitoring methods. Four levels are outlined providing a range from reconnaissance to research monitoring. Monitoring situations are presented for each monitoring level, below, to further guide the decision.

Monitoring Level One is useful as a screen to develop priorities for monitoring. It also may be useful to land managers in quickly inventorying practices that are not effective and identifying those practices that appear to be effective. This level will most likely not meet regulatory standards or the TFW strategy for effectiveness monitoring, although it may be a useful companion method to support higher levels of monitoring.

Monitoring Level Two offers the greatest opportunity for a high number of observations at a relatively low cost. It meets the TFW Monitoring Program Plan goals for effectiveness monitoring where a moderate level of certainty is appropriate.

Monitoring Level Three offers a higher level of certainty and a much higher cost. Use of this level is recommended when regional or local needs support the need for a high level of certainty.

Monitoring Level Four is research level monitoring. This monitoring is useful for validation of models and less quantitative observations.

Methods for Level Two and some Level Three monitoring are in Appendix C and procedures for monitoring are described in Part II of this document.

Table 8. Selection matrix for sediment source/delivery monitoring methods.

Monitoring Level	Implementation Compliance	Hillslope Effectiveness Monitoring (Harvest, Site Preparation, Landslide scars)	Road Effectiveness Monitoring	Restoration Effectiveness Monitoring
Level One (uses qualitative and subjective methods, high uncertainty, covers a high volume of observations at lowest cost)	Compliance checklist	On-slope: Checklist of visual indicators of presence or absence of erosion/ delivery completed by trained personnel In-stream: Visual evidence of sediment plumes and fans associated with delivery point recorded by photography or by distance of plume downstream, Stream Order, and estimated discharge.	On-slope: Checklist of visual indicators of erosion/ delivery completed by trained personnel In-stream: Photo points of sediment plumes and fans associated with delivery point	On-slope: Checklist of visual indicators of erosion/ delivery completed by trained personnel In-stream: Photo points of sediment plumes and fans associated with delivery point
Level Two (uses qualitative and quantitative methods; moderate uncertainty, site selection rarely limited by site variability)	Interdisciplinary team (forest practice forester, project administrator, soil scientist or erosion and vegetation specialist) completes compliance checklist	On-slope: Soil loss surveys (pedestals, rills, channel bank erosion; erosion pin; photo point); Estimate percent delivered by proximity and signs of slope deposits In-stream: Map extent of sediment plumes and fans associated with delivery point	On-slope: Soil Loss Surveys (pedestals, rills, erosion pin, photo point); Estimate percent delivered by model or proximity to stream and signs of slope deposits In-stream: Map extent of sediment plumes and fans associated with delivery point. Suspended sediment/turbidity grab samples (above /below).	On-slope: Comparison of volume of potential hazard and existing sediment input during recovery e.g., stream crossings, sidecast: Vegetation recovery surveys; Estimate percent delivered. In-stream: Suspended sediment/turbidity grab samples (above/below)
Level Three (uses primarily quantitative with some qualitative methods to support "weight-of-evidence approach; low uncertainty; site variability limits site selection; high cost	Level Two methods with sample size resulting in statistical significance.	On-slope: Soil loss catchment (silt fences) at delivery points In-stream*: Continuous long-term in-stream sediment sampling in combination with Level Two methods to assess relative contribution, if more than one	On-slope: Soil loss catchment (silt fences, sediment bins, culverts) at delivery points In-stream*: Continuous long-term in-stream sediment sampling in combination with Level Two methods to assess relative contribution, if more than one	On-slope: Soil loss catchment (silt fences, sediment bins, culverts) at delivery points In-stream*: Continuous long-term in-stream sediment sampling in combination with Level Two methods to assess relative contribution, if more than one

Table 8. Selection matrix for sediment source/delivery monitoring methods (cont.).

Monitoring Level	**Implementation Compliance**	**Hillslope Effectiveness Monitoring (Harvest, Site Preparation, Landslide scars)**	**Road Effectiveness Monitoring**	**Restoration Effectiveness Monitoring**
Level Four (low uncertainty, quantitative, research level)	Controlled implementation for research purposes	On-slope: Controlled environment studies (rainulator/catchment) In-stream*: Long term sediment sampling with adequate time to establish control or suitable pair sample.	On-slope: Controlled environment studies (rainulator/catchment) In-stream*: Long term sediment sampling with adequate time to establish control or suitable pair sample.	On-slope: Controlled environment studies (rainulator/catchment, measure volume of fill or sidecast removed) In-stream*: Long term sediment sampling with adequate time to establish control or suitable pair sample.

* Recommend reviewing Bunte, K. and L.H. MacDonald (1998) for a comprehensive review of in-stream sediment sampling, prior to undertaking this very expensive form of monitoring.

Implementation Compliance Evaluations

This evaluation assesses whether the practice complies with the prescribed management direction, either documented through watershed analysis prescriptions, by the Forest Practices application, or other relevant documents. The evaluation is conducted in the field with the appropriate documentation in hand. A simple checklist documenting general operations and any reasons for on-site changes completed by the project administrator during or shortly after the project is completed will assist this evaluation. If project documentation is not available, contract specifications and/or a personal interview with the project administrator are other ways of obtaining operational information about the site and the treatment.

To emphasize the importance of involving the project administrator familiar with the area, here are a few following examples of where a wrong interpretation can be made.

Example:

> *The observer is checking compliance with maintaining road drainage runoff prescription. A recent cross drain installation has created a rough and unvegetated area at a location where the road gently outslopes onto the fillslope. At first glance it may appear that road runoff has eroded the fillslope around the culvert. In fact, that did occur but the problem was remedied when the new culvert was installed and the observer was mixing old runoff features with new construction features. The observer sees a cable skid trail experiencing sheet erosion below a landing. The prescription called for full suspension. At first glance surface runoff from the landing is determined to be the trigger because the prescription called for full suspension. Upon further research it is learned that the slope of the land would not allow for full deflection below the landing and the removal of soil material was more due to mechanical disturbance than from landing runoff. In this case, non-compliance of the harvest practice may have been missed.*

If the practice is not in compliance with the prescribed practice, a diagnostic is conducted to describe what aspects of the practice are not in compliance. A brief description is included of the effects non-compliance is having on sediment delivery. Non-compliant sites should be noted and can be used in the evaluation of the management system at the watershed scale.

Erosion Source Evaluations

On-slope surveys are conducted after the practice is in place and use existing surface features (e.g., pedestals, raindrop pavement, exposed roots, rills, gullies) or an artificially placed feature (e.g., erosion pins) to assess the degree and/or origin of soil loss. These kind of surveys are useful for road cutslopes and fillslopes, ditchlines, road surfaces, harvest units, and landslide scars. Soil loss can either be addressed by percent of area eroding or quantified by comparing the original soil surface using the feature as a benchmark and the current soil surface (e.g., measuring the depth of the gully and multiplying by area). Quantitative methods can be confounded by frost heaving of erosion pins, pedestals too small or too transient to identify accurately, and interference by animals. Numerical results are a means of estimating relative rate of soil loss. In order to obtain more certainty in numerical measurements, the evaluation requires a controlled environment. Burroughs and King (1989) assessed soil loss using rain simulation and sediment catchment to isolate and control variables at their research sites. The cost and time required to conduct this level of monitoring limit its application for effectiveness monitoring. Rain simulation studies are more suited to addressing questions of validation of assumptions that will be used widely, (e.g. erosion and sediment yield model coefficients).

Channel bank surveys assess the amount of mechanical damage from harvest by unit area using a baseline "before" practice observation and "after" practice observation of channel bank integrity. These surveys are useful in designated riparian management zones (RMZs), Type 4 and Type 5 channels. Bank degeneration from accelerated stream flow is outside the scope of this survey.

Sediment Delivery Evaluations

Approaches outlined in Table 6 are sediment delivery surveys, source search surveys, and studies measuring suspended sediment or turbidity flux.

Sediment delivery surveys are the least time and cost intensive. They can provide either a yes/no finding or relative comparison of storage and delivery using soil loss estimates. Sediment delivery is identified by observing runoff trails leading to stream channels and sediment plumes that can be directly correlated to an adjacent on-slope source. These surveys can be used universally either for delivery from hillslope or road erosion.

Source search surveys typically use "grab" samples to measure suspended sediment or turbidity along with an estimate of discharge. Samples are taken above and below different treatments to identify the relative contribution of each source. A source search evaluation using the grab sample method might sample a network of tributaries or along a channel with potential erosion sources to locate significant sources of suspended sediment. Above and below grab samples provide a means of comparative sampling using the above sample as a reference condition or control.

Suspended sediment or turbidity flux studies are the most time, cost, and expertise intensive. It is difficult to obtain statistical significance. Finding sites and timing sampling to distinguishing "background sediment" from increases from practices can confound certainty in results. They require baseline studies prior to practice implementation and a representative control during instrumentation. The technical nature of the instrumentation requires frequent visits to the site.

2.6 Analysis and Reporting Results

Monitoring plans outline how the analysis will be conducted and generally what kind of information will be provided in the monitoring report. Each practice is evaluated for effectiveness using the criteria in Section 2.4. Observations of effectiveness are summarized by situational categories. If applicable, discuss results within the context of storm recurrence and “design life” required by management. If there is more than one site condition evaluated, observations are analyzed for each condition and effectiveness is compared. Any differences in effectiveness related to site characteristics and to stratification are noted. Tabular summaries are organized by TFW stratification categories to facilitate data entry into TFW’s corporate database.

Monitoring reports should include:

- A brief review of the monitoring plan’s purpose and methods
- A description of the site selection process
- A discussion of how and why methods may have been altered from the plan
- A review of the results relative to the monitoring questions/hypotheses
- A tabular summary of observations and a discussion of results
- A section on adaptive management discussing effectiveness of practices and recommended improvements
- An appendix with raw data.

A copy of the monitoring report, data, and maps showing monitoring site locations should be archived with the TFW Monitoring Program’s information system. A system for permanent data storage locally is also recommended.

3.0 Watershed Scale - Evaluation of Multiple Practices and Management Systems

Covered in this section is guidance in study design development for watershed scale evaluation of multiple practices and management systems. Discussed are elements important to developing a monitoring plan: 1) monitoring goals and objectives; 2) project scoping; 3) developing monitoring questions and hypotheses; 4) a discussion and approach for evaluating effectiveness; 5) considerations for study design; and 6) considerations in analysis and reporting results.

These guidelines are useful to those evaluating progress toward meeting management goals to reduce effects from surface erosion, such as for the TFW 5-year review, for comparing different management systems' effectiveness in reducing delivery of fine sediment to stream channels, for providing feedback for improvement of management systems (adaptive management), for screening for practices that may need further evaluation at the site scale, and for accumulating evidence of effectiveness in protecting aquatic resources.

The focus of this section, primarily, is on the evaluation of controlling the acceleration of surface erosion processes and delivery of fine sediment to the stream network. It is recognized that controlling fine sediment delivery from surface erosion is only one of the components in evaluating effectiveness in protecting the aquatic resource at the watershed scale.

Effectiveness evaluations should include other possible sources, such as, mass wasting and streambank erosion. The TFW framework for monitoring mass wasting is available from the TFW Monitoring Steering Committee, *Effectiveness Monitoring of Forest Practices and Management Systems – Mass Wasting.* A TFW framework for monitoring bank erosion has not been developed to date. Management-induced sources should be compared with natural sources to understand the relative influence management-related sediment may be having on the aquatic resource.

Integrating evaluations of input sources with an evaluation of changes in the aquatic environment over time provides an opportunity to evaluate response. This document discusses considerations for integrating channel response evaluations with input source evaluations. Procedures and methods for evaluating channel response are not included in this document but are available from other sources. References for these sources are located in Section 3.5.

If resources are limited, monitoring plans should place a priority on source/delivery monitoring over channel response. Monitoring input processes provides the best means to link increases of sediment delivery to a source and allows for analysis of practice effectiveness that can lead to recommendations for improvement. If both types of monitoring are planned, study design elements should be developed jointly.

Watershed scale, for the purposes of this document, is considered either at the Watershed Administrative Unit (WAU) level or at some aggregation of Watershed Administrative Units. Management systems currently in place and considered in this guide are Washington's Forest Practices Rules, Watershed Analysis, and Habitat Conservation Plans. Other management systems that may be considered in the evaluation are county regulations, USDA Forest Service Forest Plans, and other jurisdictional regulations operating in the watershed.

3.1 Goals and Objectives

To meet TFW program goals and objective for watershed scale monitoring, the following goal and objectives are identified to guide evaluation of management systems and multiple practices in a watershed.

Goal:

To support the TFW monitoring strategy by evaluating, at the watershed scale, the effectiveness of management systems in providing protection from delivery of fine sediment and by supporting adaptive management through recommendations to improve effectiveness.

Objectives:

1. To document and evaluate direct effects or changes in surface erosion processes, on a watershed scale, in response to multiple forest practices.

2. To evaluate if management systems are effective in recognizing surface erosion and sediment delivery hazard which prevents potential impacts to the aquatic resource.

3. To evaluate if management systems are effective in preventing adverse changes or encouraging recovery of impaired aquatic condition over time.

There are several assumptions that help support this goal and these objectives.

Assumptions:

Delivery of fine sediment from surface erosion related to management practices constitutes an accelerated influx of fine sediment over natural background rates. Adverse affects to the aquatic resource are suspected at sediment levels accelerated over background rates.

Watershed scale evaluations of accelerated erosion delivered to stream channels provide an indication of the potential effect to the aquatic resource. The degree to which management systems direct forest practices or restoration measures in controlling the delivery of fine sediment to stream channels is a measure of effectiveness of the management system.

Changes in channel diagnostic features (e.g., width, depth, bank erosion, pool frequency, particle size) and sediment load (i.e., amount and particle size distribution) over time related to observed changes in sediment supply and stream discharge may be useful in determining influences of management systems relative to influences from natural processes.

3.2 Problem Statement

The first step in developing a monitoring plan is to obtain a clear understanding of the reason for monitoring and to record them in a problem statement. A problem statement summarizes the issues and clarifies the purpose and scope of the monitoring project. It provides focus for the monitoring plan and helps communicate the context for the project to others. The problem statement may identify priorities for the monitoring project. It states the objective for the evaluation.

Issues that direct monitoring at the watershed scale are identified by several means. Regional interests in a particular element of a management system such as maintenance plans or abandonment programs may direct a cooperative evaluation over several watersheds and landowners. Five-year watershed reviews of watersheds with a completed watershed analysis may focus a higher intensity of monitoring on a category of practices needing review as determined by the analysis. If relative sediment sources and hazard are not known, a five-year review would evaluate all practices at the same intensity. A study may be designed to address a statewide interest to compare performance of several management systems. And, interest in evaluating trends in watershed aquatic resource condition may direct a long-term study to monitor both input sources and channel response in several “benchmark” watersheds.

Depending on the purpose of the evaluation, the scope of the monitoring project may be limited to certain practice types. Since the relative effect of all input sources is important to understanding the cumulative effect of multiple practices on aquatic resources, a high level of certainty is needed to exclude practice types from the evaluation. But, if a watershed analysis has demonstrated that surface erosion is the primary source of management-related sediment in the watershed and no recent logging activities have taken place, the five-year review might evaluate only road practices. On the other hand, a long-term benchmark study requires a high level of certainty over time and space of all sediment input sources, natural and management-related, to determine relationships with changes observed in a network of channel response monitoring reaches.

Below, is an example of a problem statement:

Example:

> *The Crystal Clear Waters Watershed has been managed under a watershed analysis for five years. During this time, we have used the findings from watershed analysis to prioritize road drainage upgrades, road abandonment and erosion control. Harvest prescriptions have been implemented to prevent disturbance of duff layers on steep slope gradients to prevent surface erosion. We are using the five-year review to evaluate how well watershed analysis recommendations have provided for control of management-induced fine sediment.*

The issue that directs this monitoring project is the need to conduct a 5-year review. The purpose is to provide an evaluation of watershed conditions relative to 5-year review standards by reviewing performance of multiple practices under the direction of the management system, watershed analysis. The scope of the monitoring project is all practices guided by watershed analysis with an emphasis on road drainage upgrades, road abandonment, erosion control and harvest on steep slopes.

3.3 Monitoring Questions and Hypotheses

Once the problem statement is developed, the next step is to develop monitoring questions and from these questions, hypotheses. Monitoring questions are developed from the purpose and scope of the problem statement. Hypotheses state what is expected from the findings of the evaluation. The study design is developed to prove or disprove the hypotheses.

A general framework of questions and hypotheses is provided in Table 9 to guide development of project-specific questions and hypotheses. Most watershed scale evaluations will have questions and hypotheses similar to the example. Project specific questions may address specific emphasis in the evaluation, but should meet the intent of the TFW framework.

One study design approach is to identify generically all the potential issues for a watershed and evaluate them all. In some cases, particularly in watersheds where little is known about erosion processes and effects, this approach is warranted. In most watersheds, issues unique to the watershed are known and monitoring design can be streamlined to focus on those unique issues. For those watersheds where Watershed Analysis or other basin-wide investigations have been conducted, general issues have been examined. Reading module reports and the Casual Mechanism Reports will help identify unique issues and help determine the focus in study design. Where watershed analysis has not been conducted, SEPA checklists and Forest Practice Applications may provide some insight to unique issues in the watershed. Using the local experience of forest practice foresters and cooperators will also be helpful in focusing on the important issues.

It is important to maintain an element of objectivity in designing the study and when reviewing background documents. One of the TFW framework monitoring objectives is to evaluate whether the issues have been identified correctly by the management system and the issues identified are used to guide management activities appropriately. The reader should review documentation with this in mind and structure monitoring observations to evaluate how well the analysis assumptions and recommendations measure up over time.

Depending on the level and certainty needed for the monitoring project, a wise choice may be to evaluate all issues but spend more effort on those issues that are of greatest concern. For example, some watershed analyses conducted in western Washington indicate that the relative contribution of sediment delivered to streams is, in this order, highest to lowest: landslides from roads or harvest, road construction, amount of road traffic, surface erosion from landslide scars, and hillslope erosion from harvest. A monitoring design could be stratified based on relative potential for sediment input. Of course, the relative rate and type of erosion must be evaluated for each project area to consider this kind of prioritization.

Monitoring only a sub-sample of the highest sediment producing sources is not advised for benchmark studies integrating channel response evaluations. The complexity in input and routing of sediment, spatially and temporally, warrants a thorough understanding of all input sources, both management-related and natural.

Table 9. TFW monitoring questions framework and examples of project level monitoring questions/hypotheses – watershed scale

	TFW Monitoring Question Framework	Project-level Monitoring Question Example	Project-level Hypotheses Example
1	What effects or changes in surface erosion delivered to stream channels are observed in response to multiple practices and management systems within the watershed?	*Over the last 5 years in implementing watershed analysis recommendations, has fine sediment delivered from roads and harvest practices been reduced to within acceptable levels (acceptable level established in WA of less than 50% over background)? In Springwater subwatershed, are turbidity levels maintained within Drinking Water Standards of 2 NTU at the municipal water supply intake?*	*Implementing watershed analysis recommendations for roads and harvest practices has reduced sediment input. The erosion model (WA) indicates sediment input is less than 50% over background. Reconnaissance surveys of road management practices, harvest practice, and restoration measures indicate that surface erosion and/or sediment delivery have significantly been controlled. Measurement of turbidity at the municipal water supply intake meets 2 NTU except during storm events. .*
2	Are management systems effective in recognizing surface erosion and sediment delivery hazard? What is effective or not effective about hazard identification?	*Has erosion/delivery potential been identified in a manner that provides for prevention of erosion and/or delivery from road management activities and harvest activities? (For Watershed Analysis, is the road erosion model effective in identifying delivery hazard?) What is effective or not effective about hazard identification? Are there new methods of identification that improve accuracy in identification?*	*The erosion/delivery potential map, B-4 and map unit descriptions are effective in identifying moderate and high hazard for general areas. The WA road erosion model has been effective in providing guidance for implementing erosion and/or delivery reduction practices for road management, maintenance and restoration activities. The road inventory has been effective in providing the land manager locations of high hazard and risk areas for fine sediment delivery.*
3	Are management systems controlling fine sediment input to a level that is preventing adverse change or is encouraging recovery of an impaired aquatic condition?	*Has the deposition of fine sediment in pools changed over time in the selected response reaches? Has flux in suspended sediment changed over time? What relationship is suggested between management related fine sediment input, routing of stored sediment, and inputs from natural processes and the observed change in in-channel fine sediment or other channel diagnostic features?*	*Fine sediment levels in response reaches will decline over time as accelerated input of fine sediment from management decline. A lag response is expected as stored sediment is routed through the stream network.*

3.4 Effectiveness Evaluation

Effectiveness defined in the TFW Monitoring Program Plan (1997) is as follows:

> *"When aquatic resources conditions are in the desirable range, an effective practice or management system will prevent significant impacts to fish habitat, water quality or water quantity or changes in the watershed input processes that affect these conditions. When aquatic resource conditions are less than desirable, an effective practice prevents impacts and allows, or encourage natural recovery processes."*

Evaluation of management system effectiveness in controlling affects from surface erosion can be defined as follows:

- Fine sediment delivery from forest practices and restoration measures is prevented or controlled within an "acceptable level".
- Levels of fine sediment in stream channels are within the natural range of variability for the aquatic system or levels of fine sediment in stream channels are decreasing allowing for recovery of an impaired aquatic system.

TFW Monitoring Program Plan objectives and the TFW framework monitoring questions provide a structure for evaluating the various elements of management systems that influence effectiveness.

TFW Framework Monitoring Question One

This question directs us to assess the effect or change in surface erosion and fine sediment delivery in response to multiple practices in a watershed. The evaluation for effectiveness follows a similar pathway as for site scale evaluations. Situations, representative of the various practice types and site conditions, are evaluated for effectiveness in controlling surface erosion and preventing fine sediment delivery. Because the situations are representative of the full range of practice categories and site conditions in the watershed, results from sample sites can e extrapolated to reflect conditions in the watershed. As in Figure 1 illustration of the pathway for site scale monitoring, for watershed scale, situations representative of multiple practices are evaluated for controlling surface erosion and if not, preventing delivery of fine sediment to a channel. Causes for ineffective and partially effective practices are diagnosed and improvements recommended.

There is a choice of two evaluation levels. A Level One monitoring evaluation results in a summary of percentage of activity categories and within them, practice categories that are effective or not effective. The evaluation is a qualitative assessment of representative practice types stratified by different site conditions. Level Two results in a numerical index of fine sediment input relative to a natural background using the Watershed Analysis erosion model or similar but stochastic type model. The index is compared to a standard for "acceptable level." Results are compared with previous evaluations, if available. Trend or change is an indicator of the relative effectiveness of management systems over time and can be used to compare with channel response monitoring and results from Monitoring Question Three.

Summarizing the effectiveness evaluation for either level may be misleading and risks oversimplification of findings. Observations are best described and analyzed in "raw" form. For example, report percentages by practice types or activity categories within situational categories that have been rated effective and those that have not. The numerical index in Level Two is reported as a percentage of the natural background index. The relative change of either the percentage of effect practices or percent over background sediment input over time suggests a trend in protection provided to the aquatic resource. The primary focus of the evaluation should be on the relative change or improvement by multiple practices categories directed by management systems, reporting effective practice types and management direction, and diagnosing management system direction that is not effective.

When channel response information is not available and the evaluation is compelled to draw conclusions about the relative protection of the aquatic resource, a standard approach to risk rating provides consistency in interpreting results. Table 10 outlines a risk rating matrix that has been derived from the watershed analysis (WFPB, 1997) approach to interpreting results. This matrix should be used to guide the development of conclusions and not to make conclusions about relative effectiveness in protecting the aquatic resource.

Table 10. Rating effectiveness in protecting the aquatic resource from fine sediment input. (provisional)

Relative Risk to Aquatic Resource	**Level One** (Averaged percent of situational categories effective in preventing fine sediment delivery)*	**Level Two**
Low risk of effects	>90%	<50% increase over background index
Moderate risk of effects	75-89%	50-100% increase over background index
High risk of effects	<75%	>100% increase over background index

*Remaining percentage of ineffective practices are evaluated for risk. If sediment input or potential for input is high, there may be justification to change the "relative risk" call to the next higher level. Rationale for this change should be explained.

TFW Framework Monitoring Question Two

This question directs the evaluation of how effective management systems are in recognizing surface erosion and fine sediment delivery hazard.

There are four evaluation criteria for this question:

- Hazard and triggering mechanisms are consistently identified throughout the watershed.
- Triggering mechanisms are correctly identified.
- There is a direct correlation with practice design and type with hazard and triggering mechanisms identified.
- Timing and design of practices is responsive to the level of hazard and risk to the aquatic resource.

Management systems must demonstrate all of the items listed below to be considered effective at recognizing hazard:

- Success in all four criteria elements with an adaptive management program that identifies and improves upon each of the four areas as needed or success in at least 90% of the land area in the watershed.
- A plan for addressing all high and moderate risk areas.
- Reasonable progress in mitigating high and moderate risk situations.

TFW Framework Monitoring Question Three

This question directs us to assess effectiveness in preventing adverse change or encouraging recovery of aquatic conditions. This question asks for validation that conditions of the aquatic resource are being protected. All sediment sources should be included in this evaluation. In fact, synthesis with other monitoring elements such as, large wood recruitment and fish passage will contribute to understanding the entire watershed scale picture.

There are two approaches to addressing this question with regards to effects from sediment input. The first approach is to infer protection of the aquatic resource using the evaluation of Monitoring Question One and integrating guidelines in Table 10. The second approach is to integrate the evaluation of sediment input with the evaluation of diagnostic features in selected channel response reaches.

The evaluation criteria element is trend or change in condition. The ideal context to compare change is “natural range of variability” for the aquatic system. This is not always possible. Unaffected watershed systems are limited and those that are available for comparison are rarely suitable due to a lack of similar site conditions. In most cases, natural range of variability will need to be approximated. An aid to determining reference conditions is provided in Appendix D. In some cases, confidence in reference condition is so low that trends in channel response may need to be compared from the first day when the monitoring site was established. In all cases, what ever reference approach is used, the approach must be qualified as to certainty in its relation to a natural range of variability, over time and spatially, relative to routing and deposition mechanisms in the watershed.

The following scenarios are offered to guide effectiveness evaluations:

Scenario One: EFFECTIVE (high potential for recovery or channel has a naturally high incidence of armoring)
Decreasing trend in fine sediment input from forest practices/Relative risk to aquatic resources is low (Table 10)/High residual amount of fine sediment in streambed.

Scenario Two: INEFFECTIVE
Increasing trend or no change in fine sediment input from forest practices/Relative risk to aquatic resources is moderate or high (Table 10)/ High amount of fine sediment streambed.

Scenario Three: INEFFECTIVE (high risk of adverse change)
Increasing trend in fine sediment input from forest practices/No adverse indices in channel response.

Scenario Four: EFFECTIVE
Decreasing trend in fine sediment input from forest practices/No adverse indices in channel response.

Scenario Five: EFFECTIVE
Trend in fine sediment yield from forest practices is insignificant compared to background rate/Relative risk to aquatic resources is low (Table 10).

3.5 Design Elements of Monitoring

This section covers design elements of a monitoring project. Each one of these following elements should be carefully outlined in the monitoring plan: 1) the use of stratified sampling and the identification of situational categories; 2) site selection; 3) the sampling schedule; 4) level of certainty needed and sample size; 5) monitoring methods; and 6) data analysis and reporting procedures.

3.5.1 Stratification

Stratification is a useful tool in monitoring of uncontrolled settings such as in the natural resource environment. Efficiency is improved by organizing variables into distinct sample sets. Sensitivity of the analysis can be enhanced by reducing the amount of variability or by grouping known variability into sample sets of predicted outcomes. These are called "situational categories."

The TFW Monitoring Program Plan suggests that a statewide system for stratifying monitoring situations would facilitate data management, aggregation of data sets to increase certainty in results through larger sample sizes, and extrapolation of findings, regionally. The discussion on stratification for surface erosion monitoring at the watershed scale is presented here to meet this expectation.

Presented is a hierarchical approach to stratification. This provides flexibility for statewide and local study design needs and allows for extrapolation of results to similar situations. There are similarities between stratification for site situation categories for the site scale and watershed scale so that cross references can easily be made between monitoring scales for the same practice type.

Situational categories are determined by identifying site conditions important to soil erosion and delivery processes and the practices directed by management systems that influence fine sediment delivery. Outlined in this section are the categories for site conditions and activity types for the TFW statewide framework. Several examples are provided demonstrating how further local level stratification may serve to stratify sampling further and enhance efficiency within the TFW framework.

Site characterization is an important component of monitoring and a companion to stratification. At the watershed scale, individual practices and site conditions may be grouped to categorize major differences. Minor differences are documented through site characterization. For further details on the difference between site characterization and stratification, see Section 2.5.1.

3.5.1.1 Regional Stratification Categories of Site Conditions

The same site condition categories used in stratifying individual practices and restoration measures at the site scale are used for watershed scale monitoring. There are three categories.

Table 11. TFW stratification categories for site conditions.

- Climate (Physiographic Region)
- Landtypes– a combination of Soil Parent Material Groups and Landforms
- Watershed analysis unit (WAU)

These categories are outlined further in Section 2.5.1.2 and in Appendix A. For watershed scale monitoring, landtyping becomes a useful tool in organizing a large area into a manageable number of strata to evaluate multiple practices and management systems over varying site conditions. Site conditions important to evaluating surface erosion and delivery mechanisms represented by Landtypes are: slope gradient, soil texture, slope morphology, sediment delivery efficiency, and slope hydrology. Landtypes also provide a tool to analyze basic differences in geomorphic processes that are essential in the site selection of channel response monitoring sites. Geomorphic processes and rate potentially interpreted by Landtypes are: mass wasting, surface erosion, snow avalanche, natural sediment delivery, sediment routing characteristics, and hydrologic regime. Landtypes become the basis for extrapolating monitoring results beyond a watershed.

3.5.1.2 Local Stratification of Site Conditions

Soil Parent Material Types

In general, statewide categories should be sufficient for watershed scale stratification. Sub categories may be developed within the statewide framework when useful to separate significantly different site conditions not separated by the broader statewide framework. An example may be that a watershed may have a dense or cemented glacial till and a younger glacial till that is friable. Observations in the project area indicate the friable glacial till is more permeable and perched water tables do not occur. In the dense glacial till, perched water tables are observed to be a trigger to road runoff problems and fine sediment delivery. In this example, friable glacial till and dense glacial till become two subcategories within the statewide group, Glacial Till. Subcategories should stratify only significantly different erosion situations. Any most cases, site characterization will be adequate to describe the more subtle differences in site conditions observed during monitoring.

Slope Gradient

Slope gradient categories may be an optional stratification to landtyping although these categories do not provide the geomorphic process stratification. It should be used with the statewide framework for Geology Groups of Washington (Appendix A) and only if landtypes can not be developed.

See Section 2.5.1.2 for slope gradient categories. All monitoring situations should have slope gradient described as a site characterization element in addition to the situation category, slope gradient or Landtype.

Subwatersheds

Stratifying situations by subwatershed allows for a higher certainty in conclusions when attempting to connect hillslope monitoring with channel response monitoring. Some subwatersheds may support different aquatic species dependent on the specific environment produced by a unique array of geomorphic process. Stratifying watershed scale observations by subwatershed will provide for a more specific analysis that may be compared with trend data on species or their habitat.

A combination of subwatershed, Landtypes, and reach morphology is recommended for monitoring site selection of channel response reaches. Sediment flux, hydrologic regimes, and general channel morphology can be compared between tributaries using Landtypes which aids in stratifying subwatersheds by similar and unique characteristics in the watershed. Developing a network of channel observations representative of the differences between tributaries may help make connections between flux in sediment input, routing, and deposition.

3.5.1.3 Stratification Categories of Management Systems and Multiple Practices

Forest practices are directed by variety of sources or “management systems” in a watershed. There are numerous variations on forest practice types and restoration measures directed by management systems. Watershed scale evaluations provide an overview of effectiveness of all practices. Multiple practices are stratified into logical groups that allow for enough detail that problem practices can be identified and the cause for ineffectiveness can be diagnosed.

The following categories are sufficiently broad to cover most practice and management system situations occurring in a watershed.

Table 12. TFW stratification categories for management systems.

♦ Forest Practices Rules: standard and conditioned	♦ Habitat Conservation Plan
♦ Watershed Analysis	♦ National Forest Management Plans or other
♦ Landscape Plans (proposed management system)	♦ Total Daily Maximum Load (TMDL) Plans

In addition, for TFW Framework Monitoring Question Two, the specific surface erosion/delivery hazard identification approach used by management systems becomes a local stratification. Activities directed by management systems and observations of surface erosion and delivery of fine sediment are evaluated using this strata to determine effectiveness in recognizing hazard.

There may be overlapping management systems, where a previous, no longer existing management system has left "legacy" practices. To meet TFW Monitoring Program goals, all practices including legacy practices are evaluated under current management systems recognized in the watershed. The expectation is effectiveness monitoring should include the evaluation of management system's actions in mitigating fine sediment input from legacy practices as well.

Table 13. TFW stratification categories for multiple practices.

♦ Road Design/Construction	♦ Harvest
♦ Road Management/Use - Active: heavy use or haul - Active: light/moderate use - Inactive - Abandoned	♦ Site Preparation ♦ Restoration/Mitigation
♦ Road Maintenance	

Sometimes patterns of practice types or design can be identified with “management era” of activity or location of activity. These patterns can be used to further stratify situations at the local project level. For example, often road construction and road design practices can be grouped into “management era” categories. Below is a example of “management era’s” and road design features common to several watersheds in the Olympic Peninsula Physiographic Region. An example in using location of activity might be road location (e.g., roads paralleling streams within 200 feet, midslope roads, and ridgetop roads).

Example:

Pre-60’s: Roads with cut/fill designs, few cross drains, reconstruction of old railroad grades, unconsolidated fill with buried debris.

60-70’s: Roads on steep slope gradients constructed with sliver fill and sidecast. Infrequent cross drains. Locations on steep, mid-slope positions. Often with grades less than 6 percent.

80 –90’s: Roads on steep slope gradients constructed with full bench construction. More frequent cross drains. Steeper road gradients than previous eras.

90’s+: Increased road maintenance and road drainage upgrades. Restoration measures, such as abandonment of roads. Includes older roads that have been upgraded to current standards.

3.5.2 Site Selection and Sample Size

The discussion for site selection and sample size is divided into two parts: sediment source/delivery monitoring and channel response monitoring.

Sediment Source/Delivery Monitoring

After situational categories are identified, sample size is determined based upon the level of certainty needed, the number of replications of the situational category in the watershed and the land area within the watershed of each situational category. The higher the number of replications of a situational category, the more certainty needed in the evaluation, and the larger the area represented by a category, the more extensive the observations should be.

Five year reviews:

All new activities within the last five years are evaluated for implementation compliance. For watersheds that have completed analysis, issues described in the analysis can be used to determine the relative need for certainty, thus, sample size. Situations where fine sediment input was identified as an issue in the analysis should receive a higher number of observations than situations where fine sediment input was not identified.

For watersheds without a complete watershed analysis or other objective watershed scale assessment to determine relative influence of management sources of fine sediment, all multiple practice categories should be examined to meet the same level of certainty.

Below, identification of situational categories and candidate sites is illustrated using the earlier problem statement example in Section 3.2.

Example:

> *Landtypes are stratified for Crystal Clear Waters Watershed. It is noted that the watershed falls within the East Cascade physiographic region. Twelve landtypes have been identified. Three of the landtypes delineate areas with a potential high hazard for surface erosion. One landtype is associated with very high sediment delivery efficiency. Another landtype is associated with convergent slope hydrology that is identified as a trigger for road drainage failure and delivery of fine sediment to Type 5 streams. Road drainage and cutslope erosion were identified as fine sediment input situations by the watershed analysis. Watershed analysis is the current management system and multiple practice activity categories identified are: all subcategories of Road Management; Road Maintenance, Restoration, and Harvest. The situational categories are the union between activity categories and the 4 landtypes identified with surface erosion or fine sediment delivery hazard. The map of landtypes is overlain by the map of locations of activity categories in the watershed. Of the possible 28 combinations,, only 10 exist in the watershed. Three other situational categories were identified based upon the following: Roads that parallel stream channels with road prisms within 200 feet of the floodplain (local situational category); and two categories combining low hazard landtypes with existing activity categories, road maintenance and harvest.*
>
> *The local forester is interviewed to understand where road maintenance plan and road upgrades have occurred. A new sub-category is added for road maintenance: road drainage upgraded and road drainage not upgraded. All harvest units logged within the last five years on landtypes with steep slope gradients or stream channels will be evaluated. There are a total of fifteen situational categories.*

Candidate sites are selected replicating situational categories needing a high level of certainty in results and land area represented in the watershed. Situations needing replication are determined to be roads paralleling stream channels and road management and maintenance in the 4 landtypes with high hazard.

Evaluation of hazard recognition, TFW Framework Monitoring Question Two, requires that all activities be identified so management decisions on location and design can be compared to identified hazard. A stratified sample based upon issues identified in the watershed analysis may bias the evaluation of hazard recognition. In the event that the watershed analysis or other management system misinterpreted hazard or misidentified hazard, the evaluation should be independent of the previous analysis. All practices within the 5-year review period should be included in the sample set and not stratified by issues described in the previous watershed analysis.

Channel Response Monitoring

The watershed is stratified by subwatersheds. Unique subwatersheds are identified by the distribution of Landtypes. The ideal in site selection for channel response monitoring is to establish a network of monitoring sites that may illustrate routing behavior and response over time. The more isolation of hillslope processes and other hydrologic variables, the clearer the evaluation of response may be. A network of sites is established by identifying a response monitoring area in every subwatershed that has unique conditions in site variation and management situations. In addition, two or three sites should be established in the mainstem channel representing a “mid” and “lower” mainstem position.

Low gradient reaches, less than 4 percent gradient, are candidates for selection. The reality in site selection is the challenge in finding low gradient reaches in some subwatersheds. “Step-pool” response sites may be as useful in the upper watershed network as “pool-riffle” or “pool-dune” reaches are to monitoring in mainstem channels.

3.5.3 Frequency and Timing of Sampling

Sediment Source/Delivery Monitoring

The five-year review time interval provides an adequate period for evaluating multiple practices relative to surface erosion. Vegetation recovery from surface erosion generally will occur within 5 years if conditions are adequate for recovery. The time period is short enough that the number of new practices is relatively small. In some cases, monitoring may include all new practices. As forest practice project planning can take one to several years, it may take two cycles of the five-year review to fully examine all practices under a new management system.

To assist the five-year review, supplemental implementation monitoring during implementation or within the first year of a new practice will facilitate evaluations of acute sediment delivery connected with construction. It also provides documentation at the five-year that can be summarized for reporting of implementation compliance. If there has been very little activity since the last five-year review, it may be practical to carry the few records of implementation monitoring forward to the next cycle where more extensive activity can be evaluated.

Monitoring during or immediately after a severe storm event may improve certainty in visual observation methods. It is also advised that evaluations be conducted soon after the season’s wet period, (e.g., snow melt or rain season and prior to ditch clean-out and road grading). Unless continual road maintenance is the norm for the management system, evaluations after road maintenance may miss important diagnostic features indicating delivery of fine sediment from roads.

Optimum time period for evaluating harvest is within the first and second growing season. If erosion is sustained through the second season, a significant chronic erosion source may be apparent. Erosion sustained after about the third to fifth growing season depending on natural rate of vegetative recovery is rare. If it occurs, the erosion is significantly chronic.

Channel Response Monitoring

In general, every five years is an appropriate monitoring time interval with the addition or adjustment of timing to capture channel alteration by significant storm events. A long term commitment to channel response monitoring is needed to evaluate change. A minimum of 15 years and more is a minimum with some indication that 25-30 years may be a suitable timeframe for streams west of the Cascade divide (Robison, 1996; Robison, 1998; Benda, 1995). The timeframe may also be dependent on watershed size. A shorter timeframe may be adequate for smaller watersheds with fewer variables than for larger watersheds (Benda, 1995).

3.5.4 Methods

Part II, Monitoring Procedures and Methods of this document covers in detail the procedures for evaluation of management system effectiveness. This section provides an overview.

Sediment Source/Delivery Monitoring

Level One: Effectiveness is evaluated using a field reconnaissance approach. A representative subset of multiple practices under each management system operating in the watershed is evaluated for implementation compliance and is qualitatively assessed for effectiveness in controlling erosion and/or delivery. The relative change in effectiveness is summarized for field surveyed practices and then extrapolated to the remaining unsurveyed practices.

Level Two: Each practice type within each management system is evaluated for its relative contribution of fine sediment. Site scale monitoring methods Level Two and Level Three are used to evaluate a subsample of practices. The results are extrapolated to closely similar practices. A sediment budget is calculated to contrast all sources of fine sediment (including mass wasting, channel bank erosion, and natural processes) and to evaluate change in the amount of delivery by source or practice type.

Channel Response Monitoring

No less than three response reaches are evaluated for changes or effects from fine sediment deposition or suspended sediment.

A **Level One** approach is suggested in the following reference:

Grant, G. 1988. The RAPID Technique: A New Method for Evaluating Downstream Effects of Forest Practices o Riparian Zones. USDA Pacific Northwest Research Station GTR-220.

Level Two methods are covered in the following references:

Schuett-Hames, D., A. Pleus, L.Bullchild, and S. Hall.1994. Ambient Monitoring Program Manual. TFW-AM9-94-001. Northwest Indian Fisheries Commission and Washington Timber-Fish-Wildlife, Olympia, WA.

Ramos, C. 1996. Quantification of stream channel morphological features: recommended procedures for use in watershed analysis and TFW Ambient Monitoring. TFW-AM9-96-006. Washington Timber-Fish-Wildlife, Olympia, WA.

3.6 Analysis and Reporting Results

The analysis should include an evaluation of multiple practice type under varying site conditions and an interpretation of trends in aquatic condition. Effectiveness is reported in the relative percentage of observed practices controlling fine sediment delivery and those practices that were not controlling delivery. A discussion with an explanation of cause for failure to control delivery and the relative effect on the aquatic resource is included for ineffective practices or management systems. An analysis of effectiveness of management systems to recognize surface erosion and fine sediment delivery hazard is also included.

If channel response monitoring is conducted with source monitoring, an analysis integrating understanding of input sources, influence of other variables such as stream discharge and geomorphic process, predicted effects, and observed changes in channel conditions should be used to draw conclusions about trends in aquatic condition.
All assumptions, data, and results are discussed and included in the report. Tabular summaries by TFW stratification categories are used to facilitate data entry into TFW's corporate database. A level of certainty is provided for data collection, extrapolation, field reconnaissance, and in the interpretation. If models are used, assumptions and calibration factors are documented.
An adaptive management section is included which discusses the conclusions of effectiveness of each management system and practice types and recommends any further actions or improvements, if any.

Monitoring reports should include:

- A brief review of the monitoring plan's purpose and methods
- A description of the site selection process
- A discussion of how and why methods may have been altered from the plan
- A review of the results relative to the monitoring questions/hypotheses
- A tabular summary of observations and a discussion of results
- A section on adaptive management discussing effectiveness of practices and recommended improvements
- An appendix with raw data.

A copy of the monitoring report, data, and maps showing monitoring site locations should be archived with the TFW Monitoring Program's information system. A system for permanent data storage locally is also recommended.

4.0 Quality Assurance

Monitoring is a commitment in personnel and funding resources that warrants that the outcome be useful to many. To assure that monitoring objectives are addressed appropriately, it is advised that monitoring plans be developed under the co-guidance of management personnel and technical personnel. Management personnel can help clarify purpose and scope of the project. Technical personnel should have experience in developing study designs, in performing data analysis and be a qualified analyst in Watershed Analysis. Methods may be carried out by those with a variety of skills. But it is recommended that a qualified earth scientist experienced in evaluating geomorphic processes and hazard be available to oversee field evaluation and to respond to more complex evaluation situations. The best combination of skills for field diagnosis of a practice is personnel with local knowledge of the watershed and practice implementation and personnel with experience in sedimentation processes and practices designed to control surface erosion and delivery of fine sediment. Skills needed for channel response monitoring are experience in evaluating fluvial geomorphic processes.

Reviews of monitoring plans and reports by others with monitoring experience will bring added assurance that resources are used efficiently and effectively. Review of monitoring plans and monitoring reports should be an established role of the TFW Monitoring Steering Committee.

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Appendix B: Diagnostic Key to Causes of Management-Related Surface Erosion and Fine Sediment Delivery

Note to Users:

This key guides diagnosis to causes of management-related surface erosion and delivery of fine sediment to a stream channel. The key covers the more common, and a few less common, situations and triggering mechanisms that may be encountered in forest management. No key of this kind can cover all circumstances. It is not intended to replace, but to supplement, practical experience aided by local knowledge of site and climatic conditions and history of practice performance.

The following is a description of how the key is used. The key is organized by situation, as one might first observe arriving at a site. The site examiner uses evidence at the site to detect which triggers played a role or have the potential to play a role in fine sediment delivery. Look for a similar situation described in the key. Read the list of triggers. Does this describe the site? Continue through the key to find any other descriptions that may fit the site. Once all the situations are identified, use deductive reasoning to diagnose the cause of failure or potential for failure by testing field observations against the diagnosis in the key. Determine which prescription from the key may be an appropriate corrective action or application of a practice for the site. Compare the key's prescriptions with the site's practice and evaluate the difference. Describe how the site's practice addressed or did not address the trigger. Then proceed in developing recommendations for change or adjustment of the practice using the key's prescriptions as a guide. Be sure to qualify what site factors are appropriate for the recommendations. Describe the level of confidence in the diagnosis and recommendation. Document any disagreements with the key. This serves two purposes: 1) demonstrating the key does not apply in the specific case requires systematic reasoning which assures the appropriate level of diagnosis has been conducted; and 2) the information provided can be used to continually improve and expand this guide.

Prescriptions listed in this key are purposely general to cover a variety of situations. The key is not intended to replace analysis that develops prescriptions tailored to each site. Recommendations for improvement or corrective action are arrived at through consideration of specific site conditions and local management requirements.

Table of Contents:

Diagnostic Key:

Road Management Activities:

I. Cutslope Erosion

A. Soil ravel depositing along the toe of cutslope

1. Fully or partially vegetated cutslope with toeslope removed by road maintenance of ditch.

   Probable Trigger: Removal of soil at the toe of the cutslope has steepened the angle of the cutslope beyond the angle of stable repose and beyond the stabilizing forces provided by root anchoring.

   Prescriptions that address erosion triggers or transport triggers:
   - Conduct ditch cleanout without removing toe of cutslope.
   - Design cutslope and ditch to allow for ditch cleanout without destabilizing the toe of the cutslope.
   - Continually remove sediment deposited in ditch or maintain sediment traps.

2. Cutslope with little vegetation cover with or without removal of toe by ditch cleanout.

   Probable trigger: Cutslope constructed at an angle beyond stable angle of repose.

   Prescriptions that address trigger:
   - Conduct ditch cleanout without removing toe of cutslope.
   - Use bioengineering methods to stabilize cutslope: Erosion mats to restrain ravel while root anchoring begins to reinforce soil stability; retaining walls or terraces to locally shorten slope length distance and revegetate for root anchoring.
   - Reconstruct and construct stable cutslope angles.
   - Continually remove sediment deposited in ditch or maintain sediment traps.

3. Cutslope increasing in size upslope into adjacent stand or clearcut.

   Probable trigger: Cutslope constructed at an angle beyond stability on landscapes near natural angle of repose. Headward migration of cutslope will continue until a lower slope gradient or point of slope reinforcement (e.g., stump, rock outcrop) is reached. In clearcut situations, sometimes localized surface runoff over the upper edge of the cutslope increases headward migration of the cutslope. Look for signs of runoff.

   Prescriptions that address trigger:

- Decrease slope length by terracing and revegetate for root anchoring reinforcement. Decreasing slope length must connect between point of natural anchor or break in slope to toe of cutslope to stop headward migration.
- Avoid construction of cutslopes beyond natural angle of repose on landscapes near their natural angle of repose. If necessary to do so, include bioengineering and retaining structures into the road design to control erosion from initiating.
- Note: ditch maintenance rarely mitigates this kind of erosion.

B. Shallow sloughing of soil (soil moving as a unit)

1. Perched water table or seasonal springs apparent in the cutslope. No tension cracks above the road cutslope or unevenness in roadbed grade or leaning trees proximate to the site that indicate deep seated movement.

   Probable trigger: Increase pore pressure.
   Prescriptions that address trigger:
   - Provide for artificial drainage to a stable slope position.

2. Perched water table or seasonal springs apparent in the cutslope. Tension cracks above the road cutslope or unevenness in roadbed grade or leaning trees proximate to the site that indicates deep seated movement.

   Probable trigger: Deep seated movement.
   Prescriptions that address trigger:
   - Address road prism stability and sediment transport in terms of deep seated movement.

C. Low grade or no cutslope ravel or sloughing. Low percentage of vegetation cover with some sheet erosion

1. Southerly aspect or aridic moisture regime (<10 inches precipitation annually) and/or coarse textured soil type.

   Probable trigger: Site conditions are too dry to support full vegetative cover.
   Prescriptions that address trigger:
   - Check species growing on the cutslope to see if they are known to be adapted for the site conditions. If species are not, seed or plant species that are more adapted to dry or coarse textured soils.

2. Other aspects and moisture regimes (>10 inches precipitation annually).

   Probable trigger: Species not adapted to site OR seed source can not readily germinate on roadcut soil materials OR no seed has reached the site.
   Prescriptions that address trigger:

- Check species growing on the cutslope to see if they are known to be adapted for the site conditions. If species are not, seed or plant with species that are more adapted to the site.

II. Fillslope Erosion

A. Rills or gullies in fillslope

1. Road bed gradient is outsloped toward area of fillslope erosion. Road design is outsloped with no ditch. Sheet wash, rills or gullies are evident along a continuous stretch of road.

   Probable trigger: Surface runoff from road is flowing over fillslope with force beyond the soil's erosion resistance.

   Prescriptions that address trigger:
   - Outsloped road design may not be suitable for soil type and climatic regime. Design roads to optimize runoff dispersal and use armoring where runoff is concentrated.

2. Road bed grade concentrates runoff to a portion of the fillslope. Signs of erosion are limited to where flow is concentrated.

   Probable trigger: Surface runoff from road is flowing over fillslope with force beyond the erosion resistance of the fillslope soil material.

   Prescriptions that address trigger:
   - If concentrated runoff if from water diversion out of a ditch, increase ditch maintenance.
   - Maintain road grades to slope toward ditch or roads without ditch, incorporate irregular grades into road surface to disperse runoff.
   - Armor fillslope.
   - Add cross drainage to disperse flow.
   - If no other practice is possible, add berm along outside edge of road to direct flow path to a stable point or one where sediment is not delivered to a channel. (Berms are only effective for short road lengths. Long berms can exacerbate the problem by concentrating runoff over long distances and increasing runoff energy).

B. Landslide scar erosion

Road bed grade concentrates runoff to the landslide scar causing headwater migration eroding road surface.

Probable trigger: Road outslopes concentrating runoff to landslide scar. Runoff flowing over the lip of the scar.

Prescriptions that address trigger:

- Temporary Repair: Place berm along head of landslide scar to direct runoff to a stable location.
- Temporary Repair: Construct water bar in road surface updrainage from landslide scar if outfall will be directed onto stable slope position.
- Address landslide triggers to avoid in future road construction and for permanent repair of road.
- After slope stability and runoff triggers are resolved, apply bioengineering methods to stabilize surface erosion.

C. Low grade or no cutslope ravel or sloughing. Low percentage of vegetation cover with some sheet erosion

1. Similar to cutslope erosion triggers, although fillslopes tend to revegetate within the first growing season after construction under most forest conditions.

2. New deposits of soil are apparent on top of fillslope.

Probable trigger: Sidecasting by road maintenance activities.

Prescriptions that address trigger:

- Locate stabile non-delivering disposal sites for road maintenance material.

III. Ditch Erosion

A. Ditch has downcut and widened

1. Long distances between ditch culverts or no cross drains.

Probable trigger: Amount of flow in ditch surpasses erosive resistance of material in ditch.

Prescriptions that address trigger:

- Add cross drains to reduce amount of flow in ditch.
- Armor ditch with rock.

2. Grade of ditch > 2%.

Probable trigger: Grade of ditch is too steep for erosive energy of flow.

Prescriptions that address trigger:

- Armor ditch.
- Vary ditch grade over short distances to reduce continuous high flow energy.
- Avoid steep ditch grades.

B. Cutslope of culvert catch basin is raveling or sloughing

1. Cutslope angle is steep and headward erosion of the upper edge is evident.

Probable trigger: Cutslope angle exceeds stable angle of repose.

Prescriptions that address trigger:
- Armor catch basin.
- Construct catch basins with stable cutslope angles for soil material.

2. Vegetation absent on all or the lower portion of the catch basin.

Probable trigger: Catchment cleanout removes vegetative cover that protects soils from erosion.

Prescriptions that address trigger:
- Less frequent cleanout of catchment providing ditch function is not compromised.
- Armor catch basin with rock.

IV. Roadbed Erosion

A. Rills or gullies in road surface

Probable trigger: Surface runoff on compacted road surface exceeds road surface material's resistance.

Prescriptions that address trigger:
- Apply road surfacing more resistant to erosion.
- Reduce length of road exposed to overland flow.
- Check carrying capacity of ditches and restore ditch function to handle runoff.
- Construct roads with native road surfaces at lower gradients.

B. Erosion "pavement" where fines are removed from around rock fragments in road surface

Probable trigger: Raindrop splash erosion from high intensity (This trigger often combines with the trigger listed I.V.A.).

Prescriptions that address trigger:
- Control delivery of fines to stream channel.

Harvest Related Activities:

I. Skid Trail Erosion

A. Rills or gullies in skid trails

Probable trigger: Surface runoff and gradient on compacted surface exceeds surface material's resistance.

Prescriptions that address trigger:

- Minimize compaction to maintain soil infiltration.
- Reduce length of slope by constructing waterbars in skid trails.

B. Sheetwash in skid trails

Probable trigger: Steep slope gradients, long slope lengths, and/or loss of root anchoring in soil textures subject to transport.

Prescriptions that address trigger:

- Interrupt long slope lengths with irregular gradients or angles in skid trail path.
- Reduce length of slope by constructing waterbars.
- Revegetate coarse, raveling soils to increase root anchoring of soils.

II. In-Unit Erosion

A. Broadcast burned and signs of sheetwash (e.g., pedestalled vegetation)

Probable trigger: Steep slope gradients, long slope lengths, and/or loss of root anchoring in soil textures subject to transport.

Prescriptions that address trigger:

- Limit broadcast burning to moderate slope gradients.
- Revegetate with ground cover immediately after burning.
- Restoration Practice: Stabilize through methods that address slope length, slope steepness, and root reinforcement of soils depending on severity.

B. No broadcast burning and signs of sheetwash (e.g., pedestalled vegetation)

Probable trigger: Steep slope gradients, long slope lengths, concentrated overland flow and/or loss of root anchoring in soil textures subject to transport.

Prescriptions that address trigger:

- Avoid disturbing areas immediately adjacent to rock outcrops or very shallow soils in areas of high intensity or long duration storm events. Often these small areas are sensitive to short duration concentrations of overland flow due to shallow soils and efficient runoff from bedrock.

- Restoration Practice: Stabilize through methods that address slope gradient or slope length and root reinforcement of soils depending on severity.
- Limit removal of canopy or ground disturbance on slope gradients that exceed natural angle of repose of native soils.

C. Rills or gullies not in skid trails

Probable trigger: Concentration of surface runoff.

Prescriptions that address trigger:

- Avoid concentration of road or landing drainage.
- Evaluate source of concentration, cause may be site specific.

Appendix C : **Monitoring Methods for Individual Practices – Site Scale**

Table of Contents:

Time Series Photo Point Surveys[1]
(Restoration and Hillslope emphasis)

Purpose:
To establish photo points to document change, visually, from erosion or delivery or recovery as a result of an individual practice. Examples of practices to monitor by this method are: skid trails, plots randomly selected in a broadcast burned harvest unit, small stream channels where practice influence can be isolated from other influences, road cutslopes and fillslopes, erosion control projects, stream crossing restoration, and outfall areas of cross drains. This survey is also a recommended companion survey to quantitative methods such as erosion pin surveys or catchment sampling to document visual changes as measurements are collected.

General Approach:

A time series of oblique angle photographs are taken along a point line. This point line is established in a manner to allow for subsequent photographs taken from the same viewpoint. Erosion, sediment deposition, sediment traps, runoff patterns, and other features are noted in the photographs. A site sketch illustrates permanent features and erosional or depositional features at the site and changes in features over time.

The photographic time series begins immediately after practice is in place, and is repeated after the first significant storm event, and then annually up to three years, depending on the practice being evaluated.

Materials:
Camera with date-back feature
200 or 400 ASA print film
100 meter measuring tape
compass
clinometer
survey rod
bright pink meter stick, for scale
bright pink half meter stick, for scale
survey flags
field book for notes
photo point survey field forms
sharpie or grease pencil
lead pencils
4”x5” white note cards
write-in-rain paper
Clear plastic water sample bottles
Optional: clear plastic water sample bottles

Site Selection Criteria:

Sites are established as near the time of completion of the practice and prior to a high intensity rainfall/runoff event to establish a control or baseline photograph to compare change over time. Point line segments should be chosen based on the area that is most representative of the practice in dimension and in hazard. The site should be isolated from influences other than by the individual practice.

Assumptions:

Gross changes in erosion, sediment delivery, sediment deposition and recovery (restoration) can be documented by a time series of oblique photographs taken from the same viewpoint.

Providing the area being photographed is isolated from other influences, the magnitude of change relative to the initial baseline photograph demonstrates the effect of the practice on surface erosion and/or sediment delivery.

Since this method is limited to documenting features produced by obvious delivery of fine sediment, a significant increase over background levels is concluded.

Evaluation criteria:

Effectiveness of a practice controlling hillslope erosion is demonstrated by: 1) no erosion 2) no runoff patterns showing delivery paths to a channel are observed; or 3) a similar amount of sediment is deposited on the slope well away from potential for delivery as was eroded from the source.

The effectiveness of road-related practices are demonstrated by: 1) no erosion of fillslopes observed at channel crossings; 2) no delivery of sediment to ditch lines with direct delivery to a channel; and 3) no gullies or sediment fans extending within 60 meters of a stream channel (Burroughs and King, 1989).

Effectiveness of restoration practices are demonstrated by: 1) recovery of vegetative cover that protects from surface erosion; and 2) removal of potential sources of sediment delivery.

Survey Method:

1. **Identify the survey area location on a map. Sketch area to be surveyed indicating important features of the practice and the location of the photograph point line and the permanent point used as a location benchmark.**

2. *Describe pertinent site factors related to the evaluation and the following survey site information in the field notebook.*

    Study site ID and study site location
    Point line ID, if more than one
    Brief description of practice to be evaluated (type, date of practice completion, etc.)

Brief description of permanent "benchmark" point used to locate the same photographic viewpoint.
Date, time, and observers names
Film type
Film speed
Camera used
Weather

3. *Select a permanent point near the start of the photo point network. You may want to select points to photograph. Examples for good permanent points are culverts, large stumps, a tree, and large rocks. Place a mark or flagging labeled PP on the permanent point so that it can be easily located again. Describe in the field notebook how to located this feature, and identify the location on the area sketch map. A photo may be taken of the permanent point, if necessary. (Consider that it may not be you conducting the following photographic survey).*

4. *Select the point where photographs will be taken from and mark with a survey flag. On the flag, write in permanent dark ink, VP1 (for viewpoint). If it necessary to have more than viewpoint, mark these as well. Measure and record the distance, percent slope with a clinometer, and azimuth from the permanent point to each VP survey flag. (If the sample area is linear and over 50 meters (e.g., road abandonment), use the method for sampling described in Road Cutslope/Fillslope Survey methods in this appendix.)*

5. *Identify each area photographed with a survey flag. Mark the flag with the point identification number. On 8" x 5" white card paper (or if raining, write-on-rain paper) make a photographic label. Note in large letters, Study Site ID, Point Line ID, and Point No. This card is in the area photographed taking care not to obstruct important features.*

6. *Measure the distance and azimuth from the VP survey flag and the photographic point survey flag and record in the field notebook. This will be helpful if the flags are disturbed between photographic sessions.*

7. *Continue marking and measuring each photographic point until the survey is established. The objective is to survey each viewpoint from the permanent point and each photographed area from the viewpoint so that these points can be located by survey if the flagging is disturbed.*

8. *Begin to take photographs. Make sure date-back feature on camera is turned on and has the correct date. It is best to take pictures when shadows are not on the photographic points. Place the meter stick in the photograph for scale. Stand over the VP flag and direct camera at the same azimuth direction as noted in the field notebook. Note in the field notebook what position the shot was take, standing at 5 feet above ground surface; prone, crouching, etc. Each subsequent survey must photographed from the same position.*
9. *Further considerations in designing photo lines for practices:*

   Stream Photo Surveys:

It may be desirable to take photographs perpendicular to the ground surface as in low altitude photography. This can be accomplished by suspending the camera viewing straight down at the same height. A mosaic of photographs can be created by overlapping each frame. Use the meter stick placed in the same location to identify where the frame overlaps.

Hillslope Erosion and Restoration Surveys:

Additional notes will be helpful in interpreting photographs. Note percent vegetative cover, percent of area the photographic represents of the practice, and make a sketch of the general area condition.

Photographed Sediment Delivery to Streams:

It may be difficult to capture runoff paths on film if they are subtle. Timing a visit to the site during a storm event may provide an opportunity to film runoff as it occurs through vegetation or to photograph sediment plumes at the point of delivery. Since natural light is usually diminished during rainstorms, 400 ASA film and/or a flash may enhance the film image. An additional option to photograph sediment delivery is to take water samples in clear plastic containers, above and below the delivery point. Shake the bottles to put sediment in suspension. Place the bottles on a white background labeling them similar to the photographic labels and identify whether the sample was taken above or below the point of entry. The "above" sample must be isolated from the influences of the practice or other practices and the "below" sample must be traceable back to erosion as a result of the practice.

Use of new technology:

New technology in visual recording of data is becoming available. Examples of technology currently available are digital cameras with audio notation features and Field Worker Pro software for the Newton message Pad 2000 that tags scene information to each image or group of images (Chesney,1998).

Miscellaneous Notes and Recommendations:
Care should be taken not to disturb the areas to be photographed by the observer's movements during survey establishment.

Photograph the entire length of the meter stick for scale.

Make sure the wide view of the scale is facing the camera and the numbers can be read.

Keep in mind that the final prints do not show the entire area inside the camera's viewfinder, shoot conservatively.
Take copies of the original field survey notes to the field. Safeguard original notes.

Try to capture the entire feature in one photo.

Streambank features: Shoot from center of stream channel, upstream, adjacent, or downstream of streambank. Place the scale either vertically on high banks, horizontally on long, low banks.

Sediment wedge features: Take the photos while looking downstream. Stand above or top of the stored sediment and shoot down. Place the scale horizontal to the photo direction on top of substrate.

Sediment wedge obstruction: Take the photos while looking upstream. Place the scale vertically against the storage mechanism to give a sense of the feature's height.

Skid trail features: When taking photos of water bars, place the scale vertically on the water bar, leaning back along the slope distance. When taking photos of skid trail surfaces, place the scale horizontally across the width of the skid trail tilted so that the wide part of the scale is facing the camera.

[1] *Adapted from Rashin, Ed, C. Clishe, A. Loch, and J. Bell. 1997. Review draft: Effectiveness of Forest Roads and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts. WA Department of Ecology. Olympia, WA*

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Road Use and Surface Conditions Survey[1]

Purpose:
To evaluate the effectiveness of road management practices by assessing the condition of the road surface during periods of high truck use, particularly during wet weather.

General Approach:
The surface conditions of main haul routes are assessed during wet weather surveys by sampling at transects established near a stream crossing. Conditions documented at each transect include condition of gravel surfacing, extent of fines on the road surface, ruts and potholes, and micro-topography of the road surface. Photographs are taken to document conditions. Surface drainage pathways are sketched along the study segment, and relative moisture condition of the road surface is noted.

A qualitative assessment is made of cut and fill slopes and ditches, noting evidence of erosion, vegetative cover, and slope length and angle for the contributing road segment. Log truck and light vehicle traffic is counted during the survey period. The maintenance plan and maintenance history for the road is obtained. Runoff sampling may be conducted in conjunction with the road surface condition survey.

Materials:
Study site maps and aerial photos
100 and 30 meter measuring tapes
metric carpenter's tapes
camera with date-back feature
200 or 400 ASA print film
survey flags
write-in-the-rain field book
lead pencils
road condition survey field forms
surface probe (metal rod) marked off in half-centimeter increments
2 hand-held traffic counters
write-in-rain graph paper & scales
compass
clinometer
abney hand level & level rod
hand trowel & shovel
tipping bucket raingage with datalogger

Site Selection Criteria:
Sites for this survey will be selected along haul road segments in close proximity to streams, where the stream reach upstream of the road crossing is not traversed by a main haul road within about 1 kilometer.

Assumptions:
The condition of the road surface during periods of heavy use in wet weather alters runoff

**patterns and increases fines available for transport which can increase potential for delivery to
stream channels.**

Evaluation of road surface conditions, runoff features indicating delivery, and comparing waters samples taken above and below the stream crossing provides a "weight-of-evidence" tracking the entire from erosion source to delivery.

Sediment sources that directly deliver to stream channels from roads constitutes increase over background sediment rate.

Above and below grab sampling at the stream crossing provides an indication of the relative amount over background contributed by the practice.

Survey Method:

1. **Install raingage in a location free from overhead obstructions such as forest canopy. Record rainfall at 15 minute intervals.**

2. *Describe pertinent site factors related to the evaluation and record in field notes the following general site and survey information:*

   Study site ID or road segment ID
   Survey ID
   Location and name of road
   Date and time (beginning and ending of sampling)
   Weather conditions
   Length of contributing road segment
   Gradient of road segment
   Gravel type and source (obtained from landowner records)
   Road drainage design (inslope/outslope, crowned)
   General description of road prism (cut/fill slopes, etc)
   Hillslope gradient above and below road
   Area that transect represents (number of stream crossings per mile of road type and use)

3. *Sketch the study area and characterize the road segment to be surveyed. Determine the portion of road draining directly to the stream crossing called the contributing area (e.g., road surface grading toward crossing, ditch length draining to crossing). Sketch drainage routes, cutslopes, fillslopes, berms, ditches, and location of sample transects.*

4. *Establish a 100 meter point line within the contributing area with the midpoint placed at the center of the stream crossing. At 10 meter intervals, a transect is established perpendicular to the point line. There are 11 transects that are the entire length of the road surface.*

5. *Record the following for each transect:*

**Record the width of travelway, whether the road surface is insloped or outsloped, and whether or not a corrugated "washboard" surface is apparent. Record the relative moisture
of the road surface by the following:**
Saturated: runoff or standing water is apparent
Moist: No apparent standing water, precipitation is infiltrating
Dry: No obvious moisture, fine material crumbles in palm of hand

Average dimensions of ruts or potholes using measuring tape for width and length and hand level and rod for depth.

At every two meter interval along the transect evaluate and record: 1) the relative compaction of the gravel surface by probing (e.g., soft – rod penetrates 1" or hard – no penetration) and, 2) general condition of gravel layer (thickness, gravel type, size, percent fines).

6. *Photograph each transect from the outside edge of the road. Prepare a photograph label by noting the Study Identification No., Survey Identification No. and the Transect Identification No. on a 4"x5" white rite-in-rain paper. Place in photograph area. Be sure the date-time feature is correct and engaged on the camera.*

7. *Draw on the sketch map any runoff pathways delivering sediment to the stream crossing from the road segment. Take photographs representing the different delivery pathways. Make photo labels with the same identification numbers as on the sketch map. Place these labels so that they are included in the photograph but not obstructing the feature.*

8. *Record a qualitative assessment of the condition of road cutslopes and fillslopes, noting the slope length, slope angle, degree of cover, and extent of surface erosion for the entire contributing area of the road segment. Describe the condition of drainage ditches and culverts. Be sure to include the first cross drain uproad from the stream crossing. Check the culvert outfall for delivery to the stream channel. These features also can be documented by photographs.*

9. *Monitor the rate and type of traffic per hour prior to or during the survey. (For safety, it may be best to conduct survey during break periods of traffic.) Cross check your count with the landowner's records for traffic for the past 30 days.*

10. *Obtain a history of maintenance for the 6 months prior the survey.*

11. *Collect a "below" and "above" water sample at the stream crossing at several time intervals during the survey. Either record turbidity (NTU) or place the two samples on a white sheet of paper, label site identification numbers and time, and photograph. Note the level of confidence in these samples providing a representation of delivery from the practice versus background.*

[1] Adapted from Rashin, Ed, C. Clishe, A. Loch, and J. Bell. 1997. Review draft: Effectiveness of Forest Roads and Timber Harvest Best Management Practices with

Respect to Sediment-Related Water Quality Impacts. WA Department of Ecology. Olympia, WA

Road Cutslope/Fillslope Survey[1]

Purpose:

To evaluate the effectiveness of road design practices, to evaluate erosion and delivery from new road construction practices and to evaluate road restoration practices such as abandonment and sidecast removal. Specific practices evaluated by this method are cutslopes and fillslopes as erosion sources, ditch function, and routing of sediment to stream channels.

General Approach:

Oblique angle photographs are taken of road prism features. For older roads, one timeframe is used to document road prism condition and signs of delivery. For new road construction or for road restoration practices (e.g., abandonment, unstable sidecast removal, change is recorded through a time series of photographs taken along a fixed point line along the edge of the road). Vegetative cover of cutslopes and fillslopes, extent of road surface rutting, condition of ditch line, recovery of restoration practices, signs of runoff and whether runoff delivers to the channel or is stored on the slope is recorded.

Site Selection Criteria:

Sites are selected based on road segments proximate to stream crossings or in the case of abandoned roads, several representative segments are selected that represent the entire road project. Old roads may be assessed a single time or at several times during a maintenance cycle and storm events. New roads and abandoned road practices are assessed immediately after construction and prior to a storm event and at least one more time one year later.

Materials:

Camera with date-back feature
200 or 400 ASA print film
100 meter measuring tape
compass
clinometer
metric survey rod
bright pink meter stick, for scale
survey flags
write-in-the-rain paper and field book
field forms
sharpie or grease pencil
lead pencils

Assumptions:

Substantial amounts of erosion and sediment delivery from newly constructed roads that do not stabilize adequately and recovery from restoration practices can be detected by sequential surveys which visually document road prism conditions.

Any delivery of sediment to stream channels at new road construction sites is an increase over background levels. The highest sediment delivery from roads is in the first three years after construction. Delivery to stream channels can persist for a long period of time as erosion sources are adjacent to stream crossings, or above ditches that have direct delivery to stream channels (Burroughs and King, 1989).

The amount of material at high risk for delivery (e.g. fills at stream crossings, unstable sidecast) removed during restoration practices is a measure of effectiveness of the practice in controlling sediment delivery.

Cross drains with outfalls within 60 meters of a stream channel have a probability of sediment delivery (Burroughs and King, 1989).

Survey Methods

1. *Describe pertinent site factors related to the evaluation and record in field notes the following general site and survey information:*

   Study site ID or road segment ID
   Survey ID
   Road number and milepost of survey beginning
   Brief description of features surveyed, practices evaluated
   Date
   Time
   Film type
   Camera used
   Weather
   Permanent point description

2. *Determine the segments of road that best represent the highest risk for sediment delivery. For new construction and older roads, this is most likely the area of road that directly grades to a stream crossing. Some older roads and abandoned roads may also have additional areas with high hazard in unstable sidecast with delivery potential. Select segments that best represent the various potential sediment delivery scenarios for transecting. Delineate location of the segments on the survey location map. Sketch survey areas and draw features important to the evaluation (e.g., sidecast pullback areas, cross drains, permanent "benchmark" point, and point line).*

3. *Select a permanent "benchmark" point near or in the segment to be evaluated and mark or flag with a label of PP for permanent point. Examples of permanent points are: culverts, large stumps, trees, large rocks, rebar (minimum 12 inches in length) placed in the road prism. In the field notebook describe the permanent point and how to relocate it. Note the location on the survey area sketch map.*

4. *Using a clinometer, measure the natural slope gradient of hillslope above and below the road prism. (Often roads are constructed on "break" in slope and both gradients are important to either erosion of cutslopes or delivery downslope of road).*
5. *Locate a point line along the road segment through the contributing area or other representative segment. The point line should be at least 100 meters in length. The 100 meter tape is lain along the toe of the cutslope and edge of ditch line (or road surface break if no ditch). Measure the distance and azimuth from the permanent point to the point of beginning of the point line. Transects are located are every 10 meters along the point line.*

6. *At each sample point, photograph the cutslope, waterbars, road surface, fillslope, and ditch line. If the transect is located where stream crossing restoration has occurred, photograph the upper transition area between "natural" channel and influence from the crossing removal, midpoint in the channel where the road prism has been removed, and at the lower transition between the previous crossing and the lower "natural" channel. Descend down the fillslope as far as necessary to obtain the best perspective. The Point of End (POE) of the point line along an active road may end at the first cross drain or upper end of contributing area. If so, walk the entire extent of the outfall area. Note the following road conditions factors in the field notebook at each sample point:*
   - *Feature described and photograph label*
   - *Percent of exposed soil on cutslope, fillslope, and outfall area*
   - *Evidence of erosion features (e.g. rills, gullies, stream downcutting)*
   - *Evidence of sediment storage and reason for storage*
   - *Presence of seeps*
   - *Road prism "micro" configuration (insloped, outsloped, crown, rutted, flat)*
   - *Cutslope length group (short <3 m; medium 3-10 m; high >10 m)*
   - *Cutbank slope angle using clinometer degrees*
   - *Evidence of runoff and likelihood of delivery to the stream channel (yes/no)*
   - *If outfall delivers, note the length from outfall to point of delivery*

7. *For each photograph taken, make a photograph label using a 4"x 5" white paper or card. Note on this label the Survey ID, Sample Point Number, and date. Place this label and the meter stick scale in the photograph area.*

Miscellaneous Notes and Recommendations:

Capture the entire scale (one meter or one-half meter) when taking all photographs. Make sure the wide view of the scale is facing the camera.

Keep in mind that the final prints do not show the entire area inside the camera's viewfinder, shoot conservatively.

Make copies of original field notes. Safeguard original field notes and sketches.

Try to capture the entire feature in one photo. Photos should be unbiased and representative of the sample area.

Photographing sediment wedge features: Take the photos while looking down slope. Stand above or on top of the exposed soil and shoot down. Place the scale horizontal, parallel to the photo direction on top of the substrate.

Photographing sediment wedge obstruction: Take the photos while looking up slope. Place the scale vertically against the storage mechanism to give a sense of the feature's height.

Photographing road cutbanks and fillslopes: Lean the scale vertically, along the slope. Take photograph straight on to demonstrate percent cover versus percent exposed soil. Take an additional photograph down road to illustrate down-slope transport to road surface.

Photographing road surface: Take photos looking down the road. Stand above or on top of the road surface and shoot down. Place the scale horizontal, parallel to the photo direction on top of the road surface.

[1] *Adapted from Rashin, Ed, C. Clishe, A. Loch, and J. Bell. 1997. Review draft: Effectiveness of Forest Roads and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts. WA Department of Ecology. Olympia, WA*

References:

Burroughs, E.R. Jr., J.G. King. 1989. Reduction of soil erosion of forest roads. USDA Forest Service General Technical Report INT-264. p.21.

Road Cutslope and Hillslope Erosion Pin Survey[1]

Purpose:
To document the amount and rate of soil loss from erosion sources influenced by an individual practice.

General Approach:
An erosion pin network is arrayed across potential or actively eroding areas attributed to practices. The amount of soil loss from the site is evaluated by measuring the change in surface level as measured by a permanently placed rebar. The evaluation period must include a minimum of two measurements, prior to and after a high intensity rainfall or runoff event.

Materials:
Metric carpenter's tape
Survey Rod
100 and 30 meter fiberglass tape
clinometer
3/8" rebar, .5-1.2 meters in length
survey flags
write-in-rain field notebook
field forms
sharpie or grease pencils
lead pencils

Site Selection Criteria:
Sites selection is based on areas that are representative of the practice and potential for sediment delivery to a stream channel.

Assumptions:
The change in height of the rebar above the surface is representative of the depth of soil removed or deposited. The sum of the change represents soil removed from the site.

Soil loss and an estimate of delivery percentage to stream channels from roads and in-unit erosion represent accelerated fine sediment delivered over background rates.

Survey Methods:
1. **Record the following general site information in the field notebook:**
   Study site ID
   Survey ID
   Road segment ID, road number and milepost, if relevant
   Date
   Time
   Weather
   Soil texture
   Indications of freeze/thaw

2. **Layout enough pin networks to represent a minimum of 10% of the erosion source area. An erosion pin network should be within 50-100 meters in length.**

   For Road Cutslopes:
   Lay the 100 meter measuring tape down the center of the ditch line or cutslope toe/road surface edge, starting at a permanently established point. Working down the road, establish a transect location every 10 meters along the tape. Mark a survey flag for each transect with a Transect number and Survey ID and place at the origin of the transect. In the field notebook, record for each transect location the transect number, distance from point of beginning of 100 meter tape, cutslope angle using clinometer degrees, and transect length.

   At each transect location, place rebar firmly into soil 1 meter apart going up the cutbank, starting at the line established by the 100 meter measuring tape. The last rebar should be placed at the bottom of the roots or vegetation at the upper edge of the cutbank. Note the length of the transect and for each erosion pin, a unique pin number, the original length of the pin, its length exposed above the ground surface. (A suggested approach to numbering pins is to describe in the field notes a numbering system using a grid. For a grid 5 pins by 5 pins the grid has an "X coordinate of A through E and a "Y coordinate" 1 through 5. The furthest left and bottom pin would be identified A1.) Take care not to disturb the adjacent area which may influence erosion processes. Continue establishing erosion pin network until finished.

   For Hillslope Erosion:
   Establish a permanent point of beginning and label. Record a description in the field notebook. Randomly select the exact area to begin the 100 meter point line by tossing the tape or other object over your shoulder. Where the object lands is the point of beginning. Measure distance and azimuth from the permanent point and the point of beginning. Extend the 100 meter measuring tape down the fall line (directly downslope) from the point of beginning. Erosion pin transects are set every 10 meters perpendicular along the 100 meter measuring tape. Record the slope percent measured by a clinometer along the 100 meter tape. Install the network working down slope.

   Place rebar 1 meter apart in each transect. Place a survey flag at the beginning of each transect labeling the flag with the survey identification number and the transect number. In a skid trail evaluation the transect should extend across the trail. Lengths of transects should range from 3-10 meters. Note the length of the transect and for each erosion pin, a unique pin number, the original length of the pin, its length exposed above the ground surface. Take care not to disturb the adjacent area which may influence erosion processes. Continue establishing the erosion pin network until finished.

3. **Re-measure the length of exposed erosion pins during the established timeframe. Consider re-measuring after at least one high intensity rainstorm to test the erosion potential of the site. Take care to evaluate if there has been any change in height due**

to freeze/thaw. If none has occurred, the measurements should reflect soil loss or deposition. Traverse below the erosion network to observe signs of runoff and flow pathways toward the stream channel. Estimate percent delivery rate from "footprints" of runoff and proximity to channel. Measure the length, width, and depth of sediment wedges that appear to originate from the erosion plot.

4. **Calculate total soil loss from the erosion pin network (length x width x change in length of erosion pin). Calculate soil deposition by adding sediment wedge or fan volumes. Subtract these sediment deposition volume from erosion source soil loss. The remainder is potentially delivered.**

5. **Convert the volume delivered from the test area to a total volume delivered for the entire erosion source area influenced by the practice. The total volume may be compared with a natural erosion rate using the procedure in Watershed Analysis (FPB,1995) for the same unit area to provide an index of percent over background rate.**

[1] *Adapted from Rashin, Ed, C. Clishe, A. Loch, and J. Bell. 1997. Review draft: Effectiveness of Forest Roads and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts. WA Department of Ecology. Olympia, WA*

References:

Washington Forest Practice Board, 1997. Standard methodology for conducting watershed analysis, Version 4.0. Washington Department of Natural Resources, Olympia, WA.

Rills and Gully Erosion Survey[1]

Purpose:
To document the amount and rate of soil loss from erosion sources influenced by an individual practice using existing erosion features to estimate soil loss.

General Approach:
The approach is similar to the erosion pin method. The distance between the root collar of vegetation (pedestalled) or the distance from the soil surface edge of a rill or gully to the bottom combined with the width dimension provides a volume of soil loss from the site. An estimate of the percent of the volume that was delivered provides an amount of sediment over background.

Materials:
Metric carpenter's tape
Survey rod
100 and 30 meter fiberglass tape
clinometer
survey flags
write-in-rain field notebook
field forms
sharpie or grease pencils
lead pencils

Site Selection:
Sites selection is based on areas that are representative of the practice and potential for sediment delivery to a stream channel.

Assumptions:
Dimensions of erosion features or sediment deposition wedges represent the depth of soil removed or deposited, respectively. The sum of the change represents soil removed from the site.

Soil loss and an estimate of delivery percentage to stream channels from roads and in-unit erosion represent accelerated fine sediment delivered over background rates.

Survey Methods:

1. **Record the following general site information in the field notebook:**
   Study site ID
   Survey ID
   Road segment ID, road number and milepost, if relevant
   Date
   Time
   Weather
   Soil texture

2. **Randomly select the point line location. Select a permanent point and label. Toss an object over your shoulder downslope to locate the point of beginning of a 100 meter point line location. Extend the 100 meter tape perpendicular to the slope gradient. Conduct a 100% sample along the length of the tape or the length of the erosion source area which ever is smaller. At least 10% of the erosion source area should be measured. Add more point lines to achieve 10% of the area if necessary.**

3. **Using a clinometer, measure slope gradient above and below the point line. Record the average of the two measurements in the field notebook.**

4. **Average the dimensions measured for each rill or gully or pedestal over a 3 meter strip along the point line. Record the distance between each erosion feature. If vegetation is pedestalled between points and soil surface is uniform, use root crowns as the pre-existing soil surface. The entire length between pedestalled plants becomes a part of the area of soil loss. Add dimensions for rills and gullies. The total volume (depth x length x width) is soil loss volume from the 300 m^2 area. Add volumes from each point line and note what percentage of the erosion source area this volume represents.**

5. **Traverse below the erosion transect to observe signs of runoff and flow pathways toward the stream channel. Estimate percent delivery rate from “footprints” of runoff and proximity to channel. Measure the length, width, and depth of sediment wedges that appear to originate from the erosion plot.**

6. **Calculate total soil loss from erosion transects (length x width x change in length of erosion pin). Calculate soil deposition by adding sediment wedge or fan volumes. Subtract these sediment deposition volume from erosion source soil loss. The remainder is potentially delivered.**

6. **Subtract volume measured in sediment wedges (sediment stored) from volume of soil loss from test area. The remainder is potentially delivered. Compare the estimated sediment delivery percentage and use reasoning to estimate the amount of sediment per area delivered to the stream channel.**

7. **Convert the volume delivered to a total volume delivered by the practice. The total volume may be compared with a natural erosion rate using the procedure in Watershed Analysis (FPB,1995) for the same unit area to provide an index of percent over background rate.**

[1] *Adapted from Rashin, Ed, C. Clishe, A. Loch, and J. Bell. 1997. Review draft: Effectiveness of Forest Roads and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts. WA Department of Ecology. Olympia, WA*

References:

Washington Forest Practice Board, 1997. Standard methodology for conducting watershed analysis, Version 4.0. Washington Department of Natural Resources, Olympia, WA.

Road Cross Drainage Survey (to date, has not been field tested)[1]

Purpose:
To evaluate effectiveness in placement and distance of cross drains and their outfall in dispersing road runoff and controlling sediment delivery from roads.

General Approach:
Evaluate placement and the distance between drainage structures and drainage function effectiveness by observing erosion in ditch and outfall area, measuring distance of outfall erosion, and measuring volume of erosion deposits and soil loss between outfall and channel delivery point.

Materials:
Study site maps
Hip chain at least 100 feet or longer
Tape measure
Clinometer
Camera with date-back feature
200 or 400 ASA print film
Field book for notes
Lead pencils
Field Forms

Site Selection:
This method can be used to evaluate any cross drainage structure, (e.g., metal or plastic culverts, open top box culverts, and water bars). Road segments evaluated should be stratified by the following site factors: soil parent material/geology group and landform (Landtypes); road proximity to stream channels, physiographic region (climate), slope position, and elevation. Road sample segments should be no less than one mile in length.

Assumptions:
Distance between cross drains, the amount of runoff carried in the ditch, and the height of the cross drain outlet above the forest floor effects erosive energy at cross drain outfalls.

Cross drain outfalls are purposely directed to the forest floor to deposit sediment prior to delivery to a stream crossing. Control of sediment delivery from cross drain outfalls is dependent upon: erosive energy of outfall discharge, resistance to erosion of the forest floor, and distance between outfall and the stream network.

Volume measurements of gully erosion below the outfall equal the amount of soil loss.

Length measurement of sediment transport indicates maximum contributing area for sediment delivery.

Survey Methods:

1. Identify road situations and locate road segments to be evaluated.

2. Describe pertinent general site and survey information:
   Study site ID
   Road segment or survey area ID
   Location and name of road
   Date, time, and observers' names
   Weather conditions
   Year road was constructed
   Year cross drains were constructed, if different
   Road construction design standards
   Geology formation name and local description of bedrock structure
   Soil texture
   Landslides inventoried associated with road segment

3. Note milepost at point of beginning and select a permanent feature as point of beginning (POB). Measure to the first drainage release point (DRP) from POB. (A drainage release point is any defined as the location where concentrated road runoff is diverted away from the road). Identify DRP with a unique identification number. If landowner has a numbering system for drainage structures, use that number, otherwise, construct a numbering system.

4. At the DRP, collect the following data:

   DRP Type:

CP	corrugated metal pipe	WB	water bar
LB	log box culvert	OP	open top box culvert
DO	ditch-out	BB	berm break (where berm along road shoulder runoff)
BA	bottomless arch		
OT	other – describe	OF	overflow (used where drainage overflowed road surface)
PP	plastic pipe		
PA	pipe arch	w/F	DRP has flume at outfall

   Diameter and condition: Diameter in inches; and describe any damage that may effect or has effected function.

   Origin of flow discharge: ST – stream crossing; SP - seepage in cutslope; RS – road surface runoff.

5. For all DRP's but stream crossings continue data collection as follows (for stream crossings use a culvert capacity/stream diversion potential survey to evaluate function):

   Road/Ditch gradient: use clinometer shooting in the "upstream" direction

   Contributing Tread width: Measure width of road that drains to DRP. If length of road contributing is different from POB to DRP then measure length of contributing road tread. Describe any forms of energy dissipation at the outfall (e.g., rock, log, etc). Using clinometer measure hillslope gradient below road prism. Note slope shape in both vertical and horizontal axis: concave, planar, convex and slope breaks within 100 feet below road prism. Describe . Describe age class of overstory vegetation: immature (0-20 years) or other (21+ years). Assign a qualitative rating to surface roughness of the forest floor below the outfall: low – smooth, depauperate with only litter cover; moderate – smooth with robust understory; high – uneven surface with large rocks or wood debris.

6. Describe erosion features at outfall: L – landslide; G – gully; R – rills; N – none or sediment deposition. Indicate material type that has eroded: S – sidecasted rock, organic debris; R- road fill; N – native soil materials or organic debris. Describe erosion activity level: AE – actively eroding; SE – recovering, but continuing to erode at slower rate than indicated by size of feature; ST – stable, revegetating or litter accumulation.

7. Measure dimensions of erosion features (length x average width x average depth) beginning at the first point of outfall contact with the forest floor. Note whether the erosion source area delivered. Estimate the percent of soil loss that was delivered either by comparing volume of deposition fans and soil loss or by visual estimation. Measure or estimate (if over 200 feet) from end of erosion feature to potential or existing delivery point to the stream network.

8. Continue to the next DRP measuring distance from first DRP. Assign a unique sample number and repeat steps 4-7. Continue survey until end is reached.

9. Sketch the road segment indicating the DRP's were erosion has been measured. On the sketch, indicate any important site features such as drainageways, origins of flow, and other features influencing effectiveness of the DRP. Indicate which DRP outfalls delivered to the stream network.

10. Summarize data collected by distance between DRPs, distance of erosion/delivery pathway to the stream network from DRP outfall, and site factor relationships to effectiveness of DRPs.

Miscellaneous Notes and Recommendations:
Creating a field form for data entries is recommended.

Consult methodology for rill and gully surveys for measurement techniques in averaging depth and width of these features.

[1] Adapted from Russell, P. and C. Veldhuisen. 1998. Monitoring Plan - road drainage and erosion initiation in four west-cascade watersheds. TFW Pilot Monitoring Project. TFW Cooperative/Northwest Indian Fisheries Commission. Olympia,WA.

Road Abandonment, Sidecast Removal and Stream Crossing Restoration

Purpose:
To evaluate effectiveness of road abandonment as a series of practices. Practices include sidecast pullback, sidecast disposal, stream crossing stabilization, revegetation, and drainage control.

General Approach:
The amount of sediment removed from a hazardous location and disposed in a stable location is measured to indicate restoration effectiveness. The amount of material remaining on the site with potential or active delivery is measured as increase over background rate. The percentage of reduction of sediment delivery is reported as a measure of relative effectiveness of the practice. Recovery to stable stream channels at stream crossing removal sites, stable soils, and recovery of vegetation are used as indicators of meeting long-term effectiveness goals.

Site Selection:
Segments of road with previous high or moderate hazard for sediment delivery to streams are selected for evaluation. The number and length of segments sampled is determined by the amount of site variability.

Materials:
Describe pertinent site factors related to the evaluation and record in field notes the following general site and survey information:

Study site ID
Survey ID or road segment ID
Road number and milepost of survey beginning
Brief description of features surveyed, practices evaluated
Date
Time
Film type
Camera used
Weather
Permanent point description

1. *Select at least five abandoned roads that represent a similar site situation using the TFW stratification framework. Using aerial photography mark features along the road that indicate the range of variability in site and management factors represented for the road (e.g., sidecast pullback areas, landslide scars, different classes and size of stream crossings, aspect, and different slope morphology).*

2. *Describe general site characteristics of the road segment to be examined. Include elevation, aspect, slope position (upper, mid, lower or valley), bedrock formation and structure, and soil texture.*

3. *At the beginning of the road abandonment segment, select a permanent "benchmark" point and mark or flag with a label of PP for permanent point. Examples of permanent points are culverts, large stumps, trees, large rocks, and 3/4 inch painted rebar placed in the road prism. In the field notebook describe the permanent point and how to relocate it. Begin a sketch map that will be used to record important features along the transect. Note the location and description of PP on the sketch map.*

   Using a clinometer, measure the natural slope gradient of the hillslope above and below the road prism at the PP location. (Often roads are constructed on "break" in slope and both gradients are important to either erosion of cutslopes or delivery downslope of road).

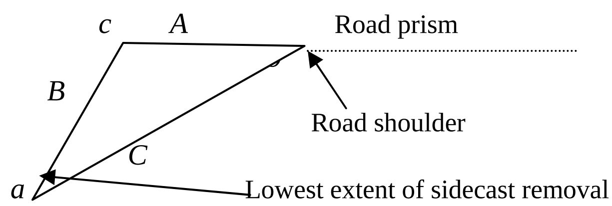
4. *Begin to survey a transect line along the road contour noting azimuth direction of line. In 100-foot increments establish an observation note point (ONP) by placing a survey pin or flagging on a permanent object in direct line of site of the azimuth from the last point. Stand over ONP and make a note of the azimuth direction toward area to describe (ATD). Along the transect line, in addition to the 100 foot increments ONP establish additional observation points that represent the sites located on the aerial photograph and any add ONPs for any significant erosion/delivery features. (Flag or mark ONP in field and note azimuth and distance between ONP in the field notebook as if someone else was going to follow your path. Anticipate that transects may be repeated several times over a ten year period and ONP and PP locations will need to be relocated). Complete the transect for the entire road.*

5. *At each observation note point (ONP), note and sketch illustration of restoration practices. Describe the following items:*

   - *Percent vegetation cover and understory/overstory species composition in road prism*
   - *Measure rills/gullies delivering fine sediment using rill and gully method*
   - *Note stable/unstable sidecast and sidecast disposal*
   - *Measure volume of unstable sidecast and estimate % deliverable*
   - *Note old erosional scars and describe percent vegetation cover and estimate % fine sediment delivering*
   - *At stream crossings, either conduct a Level Three survey or Level Two reconnaissance survey described in separate methodology.*
   - If the sample point is a disposal area, calculate sediment volume and delivery potential of runoff from the disposal site.
   - *Drainage control practices and condition. If unstable, quantify volume by measuring unstable portion that is predicted to deliver.*

   To measure sidecast, visualize existing slope gradient through road prism to where it meets the shoulder of the road. The material beyond that point is sidecast. Measure length, width and depth to calculate volume. For estimates of sidecast material removed either use contract equipment records or use Law of Sines to calculate volume.

Calculations for sidecast volume removed are as follows:



Determine angle of repose for local fill material by measuring a sidecasted fill slope with a clinometer on the slope gradient representative of the monitoring site. Use this angle for *a* (degrees) in the diagram. A reasonable default is 30 degrees if a calibration site is not available.

Measure the slope length *C* (feet) from the existing road shoulder to the lowest extent of removed sidecast. Using a clinometer measure determine natural slope angle *b* (degrees).

Find the angle of the removed sidecast shoulder: $c = 180 \text{ degrees} - (a + b)$

Find the outer length of the removed sidecast: $B = C \sin b / \sin c$

Find the old sidecast road surface: $A = B[\sin a/\sin b]$

Calculate s: $s = [A + B + C] / 2$

Find the area (AR) of the oblique triangle representing the sidecast removed:

$$AR = \sqrt{s\,(s-a)(s-b)(s-c)}$$

Calculate the volume (sq ft): V = AR x length of sidecast area

Convert square feet to cubic yards: V / 27 cu yds

Calculate fine sediment volume from the total using soil sieve analysis or estimates of fine soil fraction less than 2mm. (Soil surveys are a source for sieve analysis or ask for assistance from a soil scientist is trained to estimate fine and coarse fraction of soils).

Additional conditions to note are:

Percent of exposed soil on cutslope, fillslope, and roadbed
Evidence of sediment storage and reason for storage
Presence of seeps
If outfall delivers, note the length from outfall to point of delivery
Slope gradient above and below road prism
Aspect
Native plant community
Change in bedrock structure or soils from general description

6. *Take photographs at ONP's that illustrate significant erosion/delivery as well as an overall condition representation of the abandoned road. For each photograph taken, make a photograph label using a 8"x 5" white paper or card. Note on this label in very large letters, the Survey ID and ONP ID Number. Place this label and the meter stick scale in the photograph area.*

7. *Summarize the total volume of sidecast or stream crossing fill removed that represents a high hazard for sediment delivery. Summarize the total volume of sidecast or stream crossing fill remaining that has a high hazard for sediment delivery. Summarize volume of sediment input from other sources. Describe volume for fine sediment and coarse sediment. Describe general overall condition.*

8. *(Optional): Measure pre-abandoned road prism dimensions using watershed analysis methods (WFPB, 1997) and calculate road erosion rate for the road prior to abandonment. Calculate background erosion rate. Re-calibrate road erosion model to abandoned road erosion rates per observations. Compare the results.*

Stream Crossing Restoration Survey

Purpose:
To evaluate change in stream channel morphology after road crossing structures, (e.g., culverts, arches, bridges) have been removed.

General Approach:
Select several permanent points as view angles of stream channel and take a chronosequence of photographs, video, or other appropriate imagery. The channel width (i.e., bank full, floodplain dimension, and low flow) above, within, and below the stream crossing are described. The relative amount of fill material remaining in the channel is compared with the amount of material removed.

Site Selection:
Stream crossings were drainage structures are being or have been removed. The most optimum site is where monitoring can be conducted while equipment is operating up through five to ten years after completion.

Methods:

Describe pertinent site factors related to the evaluation and record in field notes. Be sure to included the following:

- Study site ID
- Survey ID
- Channel segment ID, if any
- Road number
  - Measured or accurately paced distance from permanent point of beginning of abandoned road to study site
  - Date
  - Time
  - Film and camera information
  - Weather
  - Stream class and stream type
  - Position on slope (upper, mid, lower, valley)

1. Use methods described for photo series surveys to establish permanent photo points for chronosequence photography.

2. Create a sketch map of the area marking and describing permanent points and features in photographs.

3. Measure width of channel in at least three locations representing the following: 1) undisturbed, immediately above the road crossing; 2) road crossing removal area, approximately midpoint within the restoration area; and, 3) historical alteration of the channel due to road crossing, below the road crossing.

4. Estimate by measuring dimensions of representative area where road fill remains within the natural channel corridor. The material in this area represents potential sediment delivery. Remeasure this

area every year the site is revisited. The measurements become validation of predicted sediment delivery.

5. Summarize findings of sediment delivery through photographic review and estimates from step 4.

Soil Loss Catchment At Delivery Points

Purpose:
To evaluate effectiveness of individual practices in controlling sediment delivery by measuring the amount of fine sediment transported to a point immediately above a delivery point of y to stream channels.

General Approach:
There are two general approaches to soil loss catchment. Devices are positioned between the erosion source and delivery point. One approach traps sediment behind a relatively impermeable device. The volume of sediment behind the device represents the volume of soil loss. The other approach captures sediment in suspension and volume is calculated from a dried sample.

Method options:[1]

***Settling Tanks* (Black, T., 1997 and Luce, 1994)**

The methods described here can be used for monitoring road tread-cutslope or skid trail erosion. The description here is for monitoring road tread erosion – cutslope erosion.

General description of method:

1. **Isolate road tread study plots hydrologically from the rest of the road system using water bars to direct water away from the top of the plot and from the bottom of the plot into the ditch. Water bars are constructed of a 30.5 cm wide by 1 cm thick segment of fabric reinforced conveyor belt bolted between two pressure treated 5.1 cm by 15.2 cm boards. Install water bars at a 30 degree angle to the roadway in a narrow trench cut into the roadway. Secure the ends of the water bars into the roadbed using 46 cm steel reinforcing bar hooks driven through eyebolts attached to each end of the water bar. To maintain road access, the trench is backfilled with gravel and compacted into place.**

   The road ditch at the top of each plot is either blocked with soil if there is little upslope drainage area, or dammed and drained to the hillslope using a 15 cm ID plastic cross drain culvert.

2. **Runoff from the plot is collected at the lower boundary using an arcuated 91 cm corrugated steel dam and a 15 cm ID plastic cross drain culvert. The cross drain delivers the suspended discharge below the road surface to a 307 gallon steel tank or box placed on a concrete pad behind a retaining wall cut into the fillslope of the road way. The retaining walls are arcuate in shape and constructed of 16 gauge corrugated rolled steel.**

3. **To measure weight of the sediment mass collected the tanks, lift tanks with a 12-ton truck mounted crane using three welded lifting points on the tanks. The lifting device includes an in line roller bearing swivel, spreader bars between three chain legs and a**

turn buckle in ine with each chain leg. The turnbuckles allow the tank to be precisely leveled under load.

A 4536 kg capacity battery powered S-beam load cell is used to weigh the tank. (A 453.6 kg steel test weight is used to calibrate the scale at the start and end of each sampling day). Fill the remaining volume of the tank with water, working the turnbuckles until water spills evenly across the top of the tank. Weigh the mass of the tank, water, and sediment. Lower the tank onto a steel c-channel frame placed beneath the road and gently spill the water out of the tank onto the forest floor or road shoulder until the tank rests on its side. Collect a composite sample of sediment at various depths from the mass of sediment left in the tank. Clean the tank with a shovel and a 1.9 cm fire hose driven by a small gas powered impeller pump.

Lift the tank and refill with water. The tank is leveled again and a second weight is recorded for the mass of water and tank. The sediment tank is then lifted above the crane and most of the water is siphoned back to the holding tank for later use. The empty tank is lowered, weighed empty, and replaced on the pad.

The weight of the sediment is calculated by subtracting the weight of water and the weight of the tank. The weight of the water has two components: the weight of water on top of the settled sediment and the weight of the water lying in the pores of the settled sediment. The weight of the column of water above the settled sediment is estimated by measuring the distance from the top of the water column to the top of the settled sediment. The weight of pore water is calculated by air drying the homogenized sediment samples taken from the tank. The air dried sample with known mass is combined with a known volume of water in a narrow calibration cylinder. This volume is used to determine the volume of the known mass of sample, or mass per unit area. Porosity of the settled sediment is calculated by adjusting for the estimated bulk density of the sediment. Measuring depth of the settled sediment, volume and weight of the pore water is determined. Subtracting the two components of water and tank weight from total weight yields weight of sediment. Depth of sediment in tank calibrated with lab analysis yields volume of sediment.

***Silt Fences* (Dissmeyer, 1982 and Dissmeyer, 1994)**

This method is useful in monitoring sediment delivery from road cutslopes and fillslopes, road ditches under a low flow regime and frequent monitoring, and all forms of hillslope erosion. It is not suitable for stream channels. The method described is for hillslope erosion. For monitoring ditch erosion, several smaller scale fabric dam structures could be adapted for the purpose substituting rebar for posts.

1. **Select monitoring sites with low runoff conditions. Monitoring plot should not exceed 100 feet in length. Monitoring of silt fences should be conducted with no less frequency than two week intervals and during or immediately after storm events.**

2. Estimate the amount of sediment predicted to be delivered to the catchment site. Design size of dam to exceed this volume. To avoid silt fences losing stability, it is better to design a higher number of silt fences than one large one.

3. Isolate the plot area using berms or other retention devices around the perimeter.

4. Set posts (6 inch diameter minimum) 4 to 8 feet apart and 19 to 24 inches into the ground. Brace posts to prevent the weight of water and sediment from pushing over the dam. Post height should be 2 to 3 feet above ground surface. Nail either a 2 by 4 inches or round top rail to the top of the posts and dig a 6 to 10 inch deep trench immediately upslope and adjacent to the posts. The dam should be placed along the contour of the slope and have wings at the ends extending straight up-slope to keep runoff and sediment from flowing around the end of the dam. Staple hog wire to the upslope side of the posts and top rail, and extend the wire down into the trench. Face the upslope side of the hog wire with geotextile fabric, which you should then wrap around the top rail and staple. Extend the fabric down into and across the trench bottom, then fill the trench with soil to anchor fabric. The fabric should be well anchored so that water will not escape under the dam.

5. To measure the amount of material stored by the dam, three methods may be used: flagged grid, surveying, shovel and weigh. The flagged grid or shovel and weigh method are recommended.

Shovel and weight method:

Shovel accumulated sediment from behind the silt dam and place in a bucket. Weigh with a spring scale. Several sediment samples should be taken to the lab to estimate average soil water content.

Flagged grid method:

Install flagged pins or ½ inch rebar on a 1 by 1 foot grid. A benchmark is established near the dam and the ground elevation at each in in the grid is measured with a rod and level. As sediment accumulates, the height of the pin above the ground surface is reduced. The volume of sediment trapped is determined by the change in elevation of each pin and multiplying the average depth of sediment deposited by the area of sediment deposited behind the dam.

6. To translate volume of sediment to weight or vica versa, bulk density is determined from a sample of the sediment.

7. To calculate total erosion rate use the following equations:

For pin method:

$$E = [GA \times \%P \times AR \times BD] / PA \times T$$

For shovel method:

$$E = SW / [PA \times T]$$

where,

E = erosion rate (tons/meters^2/yr)

GA = **Total grid area (meters^2)**
%P = **Number of grid points with sediment accumulation / total number of grid points**
AR = **Average accumulation rate (meters/yr)**
BD = **bulk density**
PA = **Total area of erosion plot (meters^2)**
T = **Time between measurements**
[1] Adapted from:

Ramos, C. 1997. Surface erosion from roads: a literature review and general recommendations for the development of a sediment monitoring strategy. Department of Earth Resources, Colorado State University. Fort Collins, CO. 66p.

References:

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Dissmeyer, G. E. 1994. Evaluating the effectiveness of forestry best management practices in meeting water quality goals or standards. Misc. pub. 1520. USDA Forest Service, Southern Region. Atlanta, GA. 179p.

Luce, C. H. 1994. Sediment production from forest roads under natural rainfall conditions. Unpublished Science Study Plan.

Stream Crossing Restoration Benchmark Survey (reserved)

Purpose:

To monitor change in channel morphology and sediment delivery during and after stream crossing restoration. The level of precision in measurement supports long-term monitoring and provides a high level of certainty in the results.

General Approach:

Surveyed permanent benchmarks are established using global positioning or more traditional benchmark methods. Channel cross sections across and longitudinally are measured at least before, immediately after drainage structure removal, one year after completion, three years after completion, and up to 15 years after completion of the restoration project.

Site Selection:

Stream crossings representing different discharge, geomorphology, and restoration objectives.

Continuous Suspended Sediment Sampling (reserved)

Purpose:
To monitor change in suspended (fine) sediment yield from a practice relative to a reference condition or natural baseline. Results may be used to establish compliance with water quality regulatory standards or where quantitative findings are needed to validate effectiveness of a practice or monitoring method.

General Approach:
Continuous suspended samplers are located above (control) and below the practice or before/above and adjacent to the practice (controls) and then above and below the practice. Measurements are taken continuously for several years. Discharge is also measured with suspended sediment.

Site Selection:
Isolation of monitoring site and the control is extremely important to obtaining some level of certainty in results. Locating a control that is representative of similar conditions as the practice area is difficult. Both of these factors limit site selection.

References:
Bunte, K. and L.H. Macdonald. 1998. Scale Considerations and the Detectability of Sedimentary Cumulative Watershed Effects. USDA Forest Service and NCASI report. Colorado State University. Fort Collins, CO.

McDonald, L.H., A.W. Smart, and RC. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. EPA/910/91-001, Seattle, WA. 166p.

Ramos, C. 1997. Surface erosion from roads: a literature review and general recommendations for the development of sediment monitoring strategy. Department of Earth Resources, Colorado State University. Fort Collins, CO. 66p.

*Appendix D: **Finding a Reference Condition***

Version 1.1 Reference
Condition